

**RISK FACTORS FOR LOWER LIMB  
MUSCULOSKELETAL INJURIES IN NOVICE  
RUNNERS: A PROSPECTIVE STUDY**

A DISSERTATION PREPARED BY RYKIE GREYBE (GRYRYK001)  
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE  
MASTER OF PHILOSOPHY DEGREE IN SPORTS  
PHYSIOTHERAPY (MPHIL SPORTS PHYSIOTHERAPY) FROM  
THE UNIVERSITY OF CAPE TOWN

FEBRUARY 2015

**SUPERVISORS:**

**DR THERESA BURGESS**

**PROF MIKE LAMBERT**

DEPARTMENT OF HEALTH AND REHABILITATION SCIENCES

DIVISION OF PHYSIOTHERAPY

GROOTE SCHUUR HOSPITAL

OBSERVATORY, CAPE TOWN

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

## Declaration

I, Rykie Greybe, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

No part of this dissertation may be reproduced, stored in a retrieval system, or transmitted in any form or means without prior permission in writing from the author or the University of Cape Town.

Signed by candidate

---

(Signature)

15 Februarie 2015

---

(Date)

## **Acknowledgements**

Many people have made this thesis a reality. Without their help and encouragement, this study would not have been possible. I would be forever grateful for everybody's valuable contribution in every aspect of this thesis:

- Dr. Theresa Burgess, my supervisor. Her hard work, encouragement and knowledge have helped me keep focus on the end result.
- Prof. Mike Lambert for his knowledge and expertise.
- Mr. Benoit Capostagno for his help with the online training log.
- To my family for their faith in me and willing ears to listen.
- To my study participants for their dedicated time and efforts.
- To Wendy Denston for helping me with the impossible task of recruiting study participants.
- To my husband, Frikkie. You have been my rock. You kept me motivated during the good and the bad times. I am forever grateful.

# Table of Contents

<b>Declaration .....</b>	<b>i</b>
<b>Acknowledgements .....</b>	<b>ii</b>
<b>List of Tables.....</b>	<b>vi</b>
<b>List of Figures .....</b>	<b>vii</b>
<b>List of abbreviations.....</b>	<b>viii</b>
<b>Abstract.....</b>	<b>x</b>
<b>Chapter 1: Introduction and scope of the dissertation .....</b>	<b>1</b>
1.1    Introduction.....	1
1.2    Aim and objectives .....	2
1.2.1    Aim.....	2
1.2.2    Specific objectives.....	2
1.3    Significance of this dissertation.....	3
1.4    Plan of development.....	3
<b>Chapter 2: Literature review.....</b>	<b>4</b>
2.1    Introduction.....	4
2.2    Endurance running.....	5
2.2.1    Endurance running as a sport .....	5
2.2.2    Benefits of running .....	5
2.2.3    Negative effects of running .....	8
2.3    Epidemiology of running-related injuries .....	11
2.4    Definitions of running-related injuries .....	16
2.5    Classification of running-related injuries.....	17
2.6    Types of running-related injuries .....	18
2.6.1    Specific running-related injuries.....	18
2.6.2    Anatomical site of running-related injuries.....	20
2.7    Risk factors for running injuries.....	21
2.7.1    Intrinsic factors .....	21

2.7.2	Extrinsic factors .....	29
2.8	Instrumentation .....	35
2.8.1	Q-angle test .....	35
2.8.2	Navicular drop .....	36
2.8.3	Active knee extension test .....	36
2.8.4	Vertical jump test .....	37
2.8.5	Balance test .....	37
2.8.6	Session rate of perceived exertion .....	38
2.9	Summary of the literature .....	39

### **Chapter 3: Risk factors for lower limb musculoskeletal injuries**

	<b>in novice runners .....</b>	<b>41</b>
3.1	Introduction.....	41
3.2	Methods.....	41
3.2.1	Research design .....	41
3.2.2	Recruitment of participants.....	41
3.2.3	Sample size calculation .....	42
3.2.4	Group allocation .....	43
3.3	Measurement instruments .....	43
3.3.1	Informed consent form .....	43
3.3.2	Physical Activity Readiness Questionnaire (PAR-Q) .....	43
3.3.3	Medical and running history questionnaire .....	44
3.3.4	Familiarisation session .....	44
3.3.5	Anthropometry .....	44
3.3.6	Musculoskeletal tests .....	45
3.3.7	Daily logbook .....	49
3.3.8	Feasibility study .....	50
3.4	Study procedure .....	51
3.5	Statistical analyses.....	51
3.6	Ethical considerations.....	52
3.6.1	Potential risk to participants .....	53
3.7	Benefits to participants .....	53
3.8	Results .....	53
3.8.1	Participants .....	53
3.8.2	Descriptive characteristics.....	54

3.8.3	Previous medical, surgical and injury history .....	54
3.8.4	Participation in other sports .....	55
3.8.5	Musculoskeletal screening tests .....	56
3.8.6	Training characteristics.....	56
3.8.7	Running-related injuries .....	60
3.8.8	Predictive factors associated with the development of running-related injuries.....	63
3.8.9	Summary of results.....	63
3.9	Discussion .....	64
3.9.1	Descriptive characteristics.....	64
3.9.2	Training characteristics.....	65
3.9.3	Running-related injuries .....	67
3.9.4	Factors predicting running-related injuries .....	69
3.9.5	Clinical implications .....	71
3.9.6	Limitations of this study and recommendations for future research	72
<b>Chapter 4: Summary and conclusion .....</b>		<b>74</b>
<b>Chapter 5: References.....</b>		<b>77</b>
<b>Appendix I - Recruitment advertisement.....</b>		<b>84</b>
<b>Appendix II - Ethics Approval .....</b>		<b>85</b>
<b>Appendix III - PAR-Q questionnaire.....</b>		<b>86</b>
<b>Appendix IV - Informed consent form.....</b>		<b>87</b>
<b>Appendix V - Novice runner Questionnaire .....</b>		<b>93</b>
<b>Appendix VI – Daily logbook.....</b>		<b>99</b>
<b>Appendix VII - Information Booklet .....</b>		<b>102</b>

## List of Tables

Table 2-1: <i>Epidemiology studies on running related injuries</i> .....	14
Table 2-2: <i>Session RPE (modified from Lambert &amp; Borreson 2006)</i> .....	39
Table 3-1: <i>Predictors variables coded for forward stepwise regression analyses</i> .....	52
Table 3-2 <i>Descriptive characteristics of participants in the injured (n=15) and uninjured (n=26) groups. Data are expressed as mean <math>\pm</math> SD.</i> .....	54
Table 3-3: <i>General sports activities of participants in the injured (n=15) and uninjured (n=26) groups. Data are expressed as numbers (n).</i> .....	55
Table 3-4: <i>Weekly frequency of training for other sports of participants in the injured (n=15) and uninjured groups (n=26). Data are expressed as numbers (n).</i> .....	55
Table 3-5: <i>Summary of the musculoskeletal tests of participants in the injured (n=15) and uninjured (n=26) groups. Data are expressed as mean <math>\pm</math> SD.</i> .....	56
Table 3-6: <i>Summary of cumulative training characteristics of participants in the injured (n=15) and uninjured (n=26) groups for the eight-week training period of this study. Data are expressed as mean <math>\pm</math> SD.</i> .....	57

## List of Figures

Figure 2.1: <i>Steps in the damage process from eccentric exercises</i> .....	10
Figure 3.1: <i>Navicular drop test. Line is drawn at the navicular tuberosity (a) Participant seated. (b) Participant standing</i> .....	46
Figure 3.2: <i>Dynamic balance - Star Excursion Balance Test</i> .....	49
Figure 3.3: <i>Weekly training distance (km) of participants in the injured (n=15) and uninjured (n=26) groups for the eight-week training period of this study. Data are expressed as mean <math>\pm</math> SD</i> .....	58
Figure 3.4: <i>Weekly training duration (min) of participants in the injured (n=15) and uninjured (n=26) groups for the eight-week training period of this study. Data are expressed as mean <math>\pm</math> SD</i> .....	59
Figure 3.5: <i>Weekly session RPE of participants in the injured (n=15) and uninjured (n=26) groups for the eight-week training period of this study. Data are expressed as mean <math>\pm</math> SD</i> .....	60
Figure 3.6: <i>Weekly injury incidence of participants (n=15) during the eight-week training period of this study. Data are expressed as numbers (n). ....</i>	61
Figure 3.7: <i>Sites of running related injuries (n=20) sustained during the eight- week training period of this study. Data are expressed as numbers (n). .....</i>	62

\* Please note: all photographs included in the dissertation were taken by the author. The models consented to their photographs being included in this dissertation.

## List of abbreviations

AKE	Active knee extension
AKI	Acute kidney injury
BMI	Body mass index
CI	Confidence interval
cm	Centimetres
CV	Coefficient of variation
d	Days
DOMS	Delayed onset of muscle soreness
EFI	Exercise-induced Feeling Inventory
EIMD	Exercise induced muscle damage
ERLP	Exercise related leg pain
FFS	Forefoot strike
hrs	Hours
ICC	Intra-class correlation
ITBS	Iliotibial band syndrome
Kg	Kilogram
LOE	Level of evidence
m	Metres
min	Minutes
Q-angle	Quadriceps angle
PAR-Q	Physical activity readiness questionnaire
PFPS	Patellofemoral pain syndrome

ROM	Range of motion
RPE	Rate of perceived exertion
RR	Relative risk
RRI	Running-related injuries
SD	Standard deviation
SEBT	Star excursion balance test
T2DM	Type 2 Diabetes Mellitus
UCT	University of Cape Town

## Abstract

**Background:** Running is popular sport in South Africa and worldwide. However, the rise in participation in running has been associated with an increase in running-related injuries (RRI). There are numerous intrinsic and extrinsic risk factors associated with RRI, and the aetiology of RRI may be multifactorial and diverse. However, few studies have prospectively examined the risk factors for injuries in novice runners. Injury often results in time off training, and may cause individuals to drop out of specific training programmes. As many individuals start running to achieve the health benefits associated with regular cardiovascular exercise, it is important to minimise any prolonged time off training, and to facilitate regular and safe participation in the sport. Therefore, an improved understanding of risk factors for RRI in novice runners is required.

**Aim and objectives:** The aim of this study was to identify the possible risk factors for the development of lower limb musculoskeletal injuries in novice runners. The specific objectives of this study were: (a) to describe the demographic and training characteristics of novice runners; (b) to establish the incidence of self-reported running-related injuries in novice runners; (c) to determine if specific intrinsic factors, namely age, gender, body mass index, quadriceps angle, foot alignment, hamstring flexibility, balance, muscle power and a history of previous injury were risk factors for lower limb musculoskeletal injuries in novice runners; and (d) to determine if specific extrinsic factors, namely training frequency, session duration, and intensity were risk factors for developing lower limb musculoskeletal injuries in novice runners.

**Methods:** The study had a descriptive, prospective, longitudinal design. Forty-one healthy novice runners were recruited for this study. Male and female participants, aged between 18 and 45 years, and who had not been running on a regular basis in the previous 12 months were included in the study. Participants who reported any relevant medical or surgical history or acute musculoskeletal injury in the past three months were excluded. Participants underwent a familiarisation session on the day of recruitment or on the day of testing. During familiarisation, participants gave written informed consent and completed the modified physical activity readiness questionnaire (PAR-Q). Participants completed a questionnaire to determine medical and surgical history, injury history and running history. Participants were familiarised with all procedures prior to the commencement of testing.

The second testing session included anthropometric measurements and a musculoskeletal assessment to evaluate specific intrinsic risk factors for RRI. Body mass and stature were recorded. The musculoskeletal assessment included the Q-angle test, the navicular drop test, the AKE test, the Star Excursion Balance Test, and the vertical jump test. All musculoskeletal assessment tests were conducted before the start of the eight-week training period. During the eight-week training period, daily training information and running-related injuries (RRI) were recorded in a logbook. The logbook information included training days, distance and duration, session rate of perceived exertion (RPE), training surface and type of training. Running-related injuries were also recorded. A RRI was defined as a “*musculoskeletal complaint of the lower extremity or back causing a restriction of running for at least one week*”. The anatomical site of pain, severity of injury and medical treatment of the injury were also recorded.

**Results:** Fifteen participants (37%) sustained a RRI during the study period, with a total of 20 RRIs being reported during the eight-week training period. Injury incidence was highest during weeks two and six of the training period. The knee was the most common site of injury. Participants reported mild to moderate pain scores associated with injury, and rested from running training for an average of three days post-injury. The majority of injured participants (n=13) managed their injuries with self-medication. Weekly training distance and duration, and session RPE were consistently higher in the injured group, compared to the uninjured group. However, participants in the injured and uninjured groups only trained on average  $25 \pm 5$  and  $22 \pm 5$  days over the eight-week study period respectively. The average session training distance and duration for participants in the injured and uninjured groups were  $5.2 \pm 1.9$ km and  $4.4 \pm 1.1$ km; and  $33 \pm 10$  min and  $28 \pm 6$  min respectively. The average session RPE was low to moderate in both groups. There were no significant differences between groups for any of the musculoskeletal screening tests. This study was unable to identify any training or biomechanical factors that were predictive of a RRI. The only predictive factor that was associated with an increased risk of RRI was a previous history of injury.

**Conclusion:** In conclusion, the findings of this study indicate that the incidence of lower limb musculoskeletal injuries in novice runners is relatively high. Careful pre-participation screening is needed to identify risk factors for injury in this potentially vulnerable group. Education is essential to ensure that runners understand the principles of exercise progression and the minimum training requirements to achieve the health benefits of regular endurance exercise, and to minimise the risk of injury.

# Chapter 1: Introduction and scope of the dissertation

## 1.1 Introduction

Running is popular sport in South Africa and worldwide. Due to the relatively inexpensive nature of the sport and related health benefits <sup>(1,2)</sup>, an increasing number of people are choosing running as a sport. The health benefits of running are predominantly linked to the cardiovascular system, improvements in quality of life <sup>(1,3-6)</sup>, and psychological benefits such as the “runners high” <sup>(7)</sup>. However, the rise in participation in running has been associated with an increase in running-related injuries (RRI). Yearly incidence rates for RRI of up to 90% have been reported <sup>(8)</sup>. Lower limb injuries account for more than 79% of all RRI <sup>(9)</sup>. This high injury rate places strain on athletes, health care professionals and health care systems. Approximately 20% to 70% of all injures lead to medical consultation <sup>(10)</sup>. In a recent study conducted on marathon runners, 16% of runners consulted a general practitioner (GP), and 24% of runners consulted a physiotherapist for RRI <sup>(11)</sup>.

Studies have examined various intrinsic and extrinsic factors that may contribute to the development of RRI. Intrinsic factors such as medical history, biomechanical variants, age, gender and body mass index (BMI) all have been associated with the development of RRI <sup>(8,10,12,13)</sup>. Previous injury has also been identified as a common predictive factor for musculoskeletal injuries <sup>(14)</sup>. In addition, training errors, environmental factors, shoes and participation in other sports are extrinsic factors that may contribute to further stress on the musculoskeletal system <sup>(8,10,15-17)</sup>. It is evident that there are numerous risk factors associated with RRI, and that the aetiology of RRI may be multifactorial and diverse <sup>(15)</sup>.

However, most studies on RRI are retrospective and it is therefore difficult to determine whether intrinsic and extrinsic factors are causative or contributing <sup>(18)</sup>. In addition, few studies have prospectively examined the predictors for injuries in novice runners <sup>(8,16,17)</sup>. With running experience being inversely related to the incidence of injuries <sup>(8)</sup> it is important to establish why novice runners may be more at risk of RRI.

Injury often results in time off training, and may cause individuals to drop out of specific training programmes <sup>(19)</sup>. As many individuals start running to achieve the health benefits associated with regular cardiovascular exercise<sup>(2,12,17)</sup>, it is important to minimise any prolonged time off training, and to encourage regular and safe participation in the sport <sup>(19)</sup>. Therefore, an improved understanding of risk factors for RRI in novice runners is required.

## **1.2 Aim and objectives**

### **1.2.1 Aim**

The aim of this study was to prospectively determine the risk factors for lower limb musculoskeletal injuries in novice runners.

### **1.2.2 Specific objectives**

Specific objectives of this study were:

- (a) To describe the demographic and training characteristics of novice runners.
- (b) To establish the incidence of self-reported running-related injuries in novice runners.
- (c) To determine if specific intrinsic factors, namely age, gender, body mass index, quadriceps angle, foot alignment, hamstring flexibility, balance, muscle power and a history of previous injury were risk factors for lower limb musculoskeletal injuries in novice runners.
- (d) To determine if specific extrinsic factors, namely training frequency, session duration, and intensity were risk factors for developing lower limb musculoskeletal injuries in novice runners.

### **1.3 Significance of this dissertation**

Running is a popular form of exercise, and has numerous health benefits<sup>(3-6,20)</sup>. However, running is associated with a high incidence of musculoskeletal injury<sup>(8)</sup>, which may both limit current participation<sup>(8)</sup> and prevent future participation in the sport. This study may identify factors related to the development of musculoskeletal injuries in novice runners. In addition, the prospective nature of the study design may allow us to determine potential causative factors of injuries. The findings of this study may therefore make an important contribution to the existing literature regarding RRI. This study might also contribute to the development of guidelines for injury prevention in novice runners.

### **1.4 Plan of development**

In preparation for the investigational phase of this dissertation, a review of the literature related to the development of RRI will be presented (Chapter 2). This will be followed by a prospective study that was designed to identify potential risk factors for the development of RRI in novice runners (Chapter 3). A summary and conclusion section, including recommendations for future research (Chapter 4) will complete this dissertation.

## Chapter 2: Literature review

### 2.1 Introduction

Participation in running activities is rapidly increasing<sup>(21)</sup>. Running is a popular choice of exercise because of its accessibility and it is relatively inexpensive<sup>(1)</sup>. With the increase in popularity, the incidence of RRI has also increased<sup>(8,9,15)</sup>.

With incidence rates for RRI as high as 90%<sup>(8)</sup>, novice runners might be hesitant to start a training programme. Numerous studies on the risk factors for RRI exist but inconsistencies and conflicting results have been found<sup>(8,13,16,21)</sup>. Different methodologies, definitions of RRI, outcome measures and study populations might be some of the possible reasons for differences in findings between studies<sup>(16)</sup>.

The main purpose of this literature review is to outline the current research on risk factors for RRI. The benefits and negative aspects of endurance running will be discussed, followed by the epidemiology of RRI. The differences in the definitions of RRI in the literature will be reviewed, and the different types of RRI will be described. The intrinsic and extrinsic predisposing factors to RRI will be discussed. Lastly, the study instrumentation will be reviewed.

For the literature review, a search was performed in PubMed, MEDline and EBSCO databases. Titles and abstracts were used to determine whether the study met the eligibility criteria. Keywords used included: “*running injuries*”, “*risk factors*”, “*overuse injuries*”, “*running training programmes*”, and “*endurance running*”. The year of the publications ranged between 1989 and 2014. Studies were included if they examined lower limb injuries in novices, recreational, or elite runners. Both retrospective and prospective studies were examined. Articles were also included if the study participants were sprinters, or predominantly exposed to types of sporting activities other than running, such as triathlons, or team sports, such as rugby, because participation in other sports while commencing a running programme has also been identified as a possible risk factor for injury<sup>(17,22)</sup>.

## **2.2 Endurance running**

### **2.2.1 Endurance running as a sport**

The popularity of endurance running has increased remarkably over the past 30 years<sup>(23)</sup>. Running is a common choice of exercise for many because of its accessibility and that it is regarded as being relatively inexpensive<sup>(1)</sup>. It is also possible to participate at both recreational and competitive levels<sup>(24)</sup>. Novice runners often participate in a training programme for the health benefits, while intermediate runners use it to improve their personal performance<sup>(18)</sup>. The Royal Dutch Athletic Federation (KNAU) estimates that 12.5% of the Dutch population run on a regular basis<sup>(17)</sup>. An estimated 30 million people run in the United States of America, and 10 million of those runners run on more than a 100 days per year<sup>(25)</sup>. The New York City Marathon is the largest marathon in the world and grew from 55 finishers in 1970 to 50304 finishers in 2013<sup>(26)</sup>. In South Africa, a similar trend has been observed. An estimated 1000 road races are held annually in South Africa, with the Comrades Marathon probably being the most well-known race in the country. In 2012, 19524 participants entered the race of which 18113 were South African<sup>(27)</sup>. In 2014, 17029 runners started the Comrades Marathon and 11991 finished in the 12- hour cut off time<sup>(27)</sup>.

### **2.2.2 Benefits of running**

The emphasis on health and weight control has increased over the last few decades<sup>(28)</sup>. With the rates of obesity and chronic disease climbing, health practitioners are advising patients on exercise regimes to lose weight, improve cardiovascular fitness and help to prevent chronic disease<sup>(28)</sup>. According to the American Council of Sport Medicine (ACSM), the amount of weekly physical activity recommended for adults is at least two hours and thirty minutes a week of moderate exercise or one hour and fifteen minutes of vigorous activity<sup>(3)</sup>.

### 2.2.2.1 Cardiovascular and metabolic benefits

The well-known benefits of running include cardiovascular fitness, strength and endurance <sup>(6)</sup>. Running might even lower the risk for developing hypertension <sup>(6)</sup>, diabetes, cancer and other diseases of lifestyle <sup>(4)</sup>. Physiological and metabolic changes, such as altered blood flow to active muscles, increased heart rate, breathing rate and oxygen consumption, are seen during an exercise bout <sup>(5)</sup>. With repeated exercise sessions, these changes induce chronic adaptations or training adaptations <sup>(29)</sup>. Training adaptations result in change of muscle morphology, altered metabolism and changes in neuromuscular recruitment patterns<sup>(5)</sup>. In endurance training, adaptations such as increased plasma volume, increased mitochondria in skeletal muscle, increased capillarisation, cardiac hypertrophy and increased density of bones, have been noted <sup>(29,30)</sup>. Resting heart rate also decreases with endurance training <sup>(5)</sup>.

There is an inverse dose-response relationship between physical activity and various chronic conditions <sup>(31)</sup>. These include obesity, type 2 diabetes mellitus (T2DM) and colon cancer. A recent study examined the effect of life-long activity in fifteen exercising T2DM patients compared to twelve sedentary T2DM patients <sup>(31)</sup>. Long-term regular exercise was defined as participation of more than 2.5 hours of endurance exercise per week, and this was performed by patients aged 18 to 47 years. The results of the study found the life-long active T2DM participants had superior fitness levels and decreased cardiovascular risks compared to the sedentary participants <sup>(31)</sup>.

Weight loss is often a big motivation for people to start an exercise programme, and often specifically running training. King et al <sup>(28)</sup> observed fifty-eight sedentary overweight/obese men and woman during a 12-week supervised aerobic exercise intervention. All participants had a body mass index (BMI) of more than 31.8 kg.m<sup>-2</sup>. The intervention consisted of five exercise sessions a week, undertaken at 70% of maximum heart rate and expending approximately 500 kcal per session. Measurements were taken at 0 and 12 weeks respectively. King et al <sup>(28)</sup> found a supervised aerobic exercise intervention can benefit the individual by significantly increasing aerobic capacity, decreasing systolic and diastolic blood pressure and resting heart rate. Interestingly, this study also found significant and meaningful health benefits can be achieved even if the participants did not show any weight loss <sup>(28)</sup>.

### 2.2.2.2 Muscle adaptation to endurance training

Endurance training improves muscle strength and performance over time. This might be due to the stimulation of muscle protein anabolism as well as the increase in mitochondrial biogenesis<sup>(5)</sup>. Harber et al<sup>(32)</sup> studied the protein synthesis in two muscle groups in eight endurance athletes. Mixed-muscle protein synthesis [fractional synthetic rate (FSR)] and gene expression were examined in the vastus lateralis and soleus muscles of eight men ( $26 \pm 2$  years) before and after a 45-minute level-grade treadmill run. The results showed that both the vastus lateralis and soleus muscles are equally responsive to running exercise at the level of protein synthesis. It also demonstrated that gene expression occurs in response to exercise which, if accumulated over repeated exercise sessions, may lead to muscle-specific adaptations in response to repetitive running training<sup>(32)</sup>.

In a study on 18 endurance athletes, explosive strength training produced a significant improvement in the 5-km running performance in the experimental group<sup>(33)</sup>. The experimental group consisted of ten elite male cross-country runners and the control group consisted of eight runners. Training volume was kept the same in both groups but 32% of training in the experimental group and 3% in the control group was replaced by explosive-type strength training. After a nine-week intervention period, the 5-km time in the experimental group was significantly improved. It was suggested that this improvement may be due to improved neuromuscular characteristics that were transferred into improved muscle power<sup>(33)</sup>.

It is noted that both these studies were on elite endurance runners, which could have influenced the study outcomes. Future research on the effect of endurance training on muscle adaptation in novice runners is suggested.

### **2.2.2.3 Psychological benefits**

Individuals may also benefit psychologically from exercise. The “runners high” may be attributed to increased serotonin levels <sup>(7)</sup>. This may aid in the prevention and treatment of depression and other psychological conditions. King et al <sup>(28)</sup> found that following the 12-week training intervention, most of the participants benefitted psychologically. An acute improvement in their psychological state was maintained during the 12-week intervention period of general exercises.

Szabo et al <sup>(34)</sup> examined the psychological and running characteristics of 50 runners. The Exercise-induced Feeling Inventory (EFI) was used pre- and post-run to determine the effects of the exercise bout. The EFI is a 12-item Likert scale, rated from 0 to 4, that measures four distinct states of effect: (1) positively engaged (enthusiastic, upbeat, happy), (2) revitalized (energetic, refreshed, revived), (3) tranquil (calm, peaceful, relaxed), and (4) physically exhausted (fatigued, tired, worn out). The study also examined the association between running characteristics, namely, duration, distance and speed, and different domains of the EFI. The study concluded that running variables may account for only a few of the positive psychological changes observed. The authors concluded that positive psychological benefits may occur irrespective of the running distance, duration or speed <sup>(34)</sup>.

### **2.2.3 Negative effects of running**

Running has many benefits <sup>(4,6,9)</sup> but the negative side also needs to be considered when starting any new training programme. Some of the negative effects of endurance running include: exercise-induced muscle damage (EIMD), delayed onset muscle soreness (DOMS), overtraining, acute kidney damage and running-related injuries (RRI) <sup>(4,6,9,15,18,29)</sup>.

### **2.2.3.1 Exercise-induced muscle damage and delayed onset of muscle soreness**

Exercise-induced muscle damage occurs as a result of unaccustomed exercise and lengthening muscle actions are more associated with muscle damage <sup>(5)</sup>. Typical symptoms of muscle damage are delayed onset muscle soreness, prolonged decrease in muscle strength and increases in muscle proteins, such as creatine kinase. Tsatalas et al <sup>(35)</sup> studied the effect of exercise-induced muscle damage on running kinematics in nineteen women. A maximal eccentric muscle damage protocol of the knee extensors and flexors were performed after which lower body kinematics during level running was assessed pre-and 48 hours later. Results showed step length decreased and stride frequency significantly increased 48 hours post-exercise at a faster running speed. Knee flexion at foot contact, pelvic tilt and obliquity significantly increased, whereas hip extension during stance-phase, knee flexion during swing-phase, as well as knee and ankle joints range of motion significantly decreased 48 hours post-exercise <sup>(35)</sup>.

Delayed onset muscle soreness (DOMS) usually develops within 24 to 48 hours after unaccustomed, high-intensity physical activity <sup>(4)</sup>. It appears to be more severe after eccentric exercise, such as downhill running <sup>(4)</sup>. Delayed onset muscle soreness is a consequence of a series of events in the muscle fibres which cause an uncontrolled release of calcium in the sarcoplasm <sup>(29)</sup>. Regular training can decrease the risk for developing DOMS <sup>(4)</sup>. An overview of the sequence of events following intense or unaccustomed exercise, leading to exercise-induced muscle damage is shown in Figure 2.1. A detailed review of the underlying mechanisms of exercise-induced muscle damage and DOMS is beyond the scope of this literature review. Please refer to Marcora & Bosio<sup>(36)</sup> and Murase et al <sup>(37)</sup> for a thorough overview of exercise-induced muscle damage and DOMS.

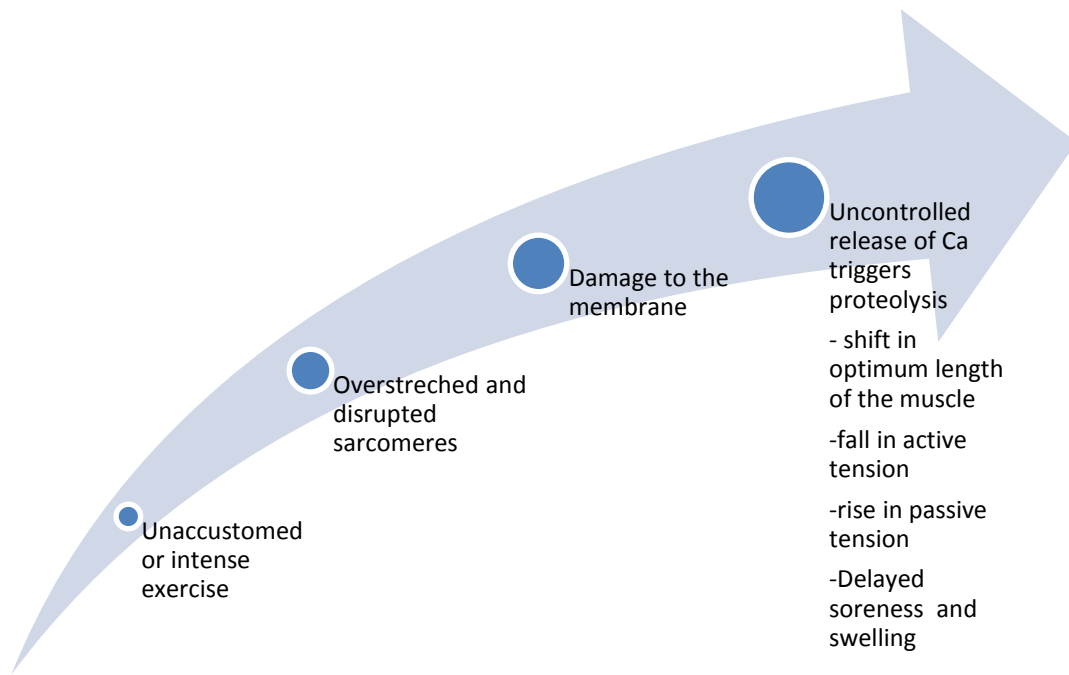


Figure 2.1: Overview of the sequence of events following unaccustomed or intense exercise that lead to exercise-induced muscle damage and DOMS.

### 2.2.3.2 Overtraining

Positive overtraining may be regarded as a positive adaption to a training programme, resulting in improved performance <sup>(38)</sup>. The opposite, however, the negative effects of overtraining, also occur. This is when maladaptation and negative consequences, such as staleness, psychological, biochemical and immunological symptoms, take place <sup>(38)</sup>. It is a common cause of persistent tiredness in sportspeople, and fatigue is often the initial symptom of overtraining <sup>(4)</sup>. Psychological testing may reveal early warning signs more readily than the various physiological or immunological markers and for that reason the ratings of perceived exertion (RPE) scale was developed. The session RPE scale rates the overall difficulty of the exercise bout <sup>(29)</sup>. To prevent overtraining the correct balance between training load and recovery is necessary <sup>(4,38)</sup>.

Denadai et al <sup>(39)</sup> studied the effects of high-intensity running to fatigue on isokinetic muscular strength in endurance athletes. All participants were healthy male middle- and long-distance runners.

The study established a reduction in isokinetic peak torque, as well as concentric and eccentric contractions of the knee extensors after high-intensity exercise. This reduction in muscle contraction may predispose a runner to the development of RRI due to muscle fatigue <sup>(39)</sup>.

### **2.2.3.3 Acute kidney injury**

Marathon running has been associated with acute kidney injury (AKI) <sup>(40)</sup>. In a study on marathon runners, 40% of healthy, well-trained runners showed evidence of AKI 24 hours after completing the marathon. Magnetic resonance imaging (MRI) and blood/urine biomarkers were performed, and a rise in serum creatine kinase activity was measured. However, the impact of repetitive episodes of AKI in marathon runners still needs to be investigated.

### **2.2.3.4 Running-related injuries**

Running-related injuries (RRI) are musculoskeletal injuries associated with the participation in running. Various intrinsic and extrinsic factors for RRI have been described. The epidemiology, type, and areas of RRI, as well as risk factors associated with RRI will be discussed in the following sections.

## **2.3 Epidemiology of running-related injuries**

Two-thirds of runners will experience at least one RRI in a year <sup>(8)</sup>. A wide range incidence data of RRI have been noted in the research ranging from 24% to 90% <sup>(8,16,18)</sup>. This wide range of data might be dependent on the type of study done, the definition of RRI and the study population <sup>(16)</sup>.

In a prospective study on 629 novice and recreational runners, 25.9% of runners experienced at least one RRI during an eight-week study period <sup>(17)</sup>. All participants were preparing for a 4 mile (6.4km) running event. A demographic questionnaire provided information regarding age, gender, BMI, current and past musculoskeletal injuries of the lower limb, running experience and current running routine<sup>(17)</sup>.

Any participation in other sports and the reason(s) for entering the programme were also assessed. A personal running diary (logbook) was kept during the eight-week preparation, which included recording any RRI. A RRI was defined as “*any musculoskeletal pain of the lower limb or back causing a restriction in running for at least one day*”<sup>(17)</sup>. The lack of running experience was found to be the biggest risk factor in both male and female participants in this study<sup>(17)</sup>.

Buist et al<sup>(21)</sup> studied the predictors of RRI in 532 novice runners. A baseline questionnaire and an orthopaedic assessment were conducted at the start of a 13-week training programme. RRI were self-reported and had to cause a restriction of running for at least a week. Twenty-one percent of novice runners reported a RRI, with male and female runners having different risk profiles<sup>(21)</sup>. It has to be noted that during this study, the RRI had to result in a total cutback of running to be classified as a RRI. Minor injuries that did not cause the participant to stop running may not have been recorded.

In an older study by Bovens et al<sup>(41)</sup>, a higher incidence rate of 85% was noted. This study was undertaken on 115 novice runners with little or no running experience. The study period was over 18 to 20 months. The participants increased their distances during the training period to ultimately run a marathon (42.2km). An interesting finding was that even though the number of injury cases per week gradually increased over the experimental period, it decreased when expressed in exposure time (1000 training hours)<sup>(41)</sup>.

Taunton et al<sup>(2)</sup> had a much lower incidence rate (29%) in a prospective study on 844 recreational runners, but this could be due to the study population’s graded training programme. No orthopaedic assessment was done in this study and only a questionnaire was used to collect data. A running injury was self-reported and recall bias could have occurred regarding previous running injuries.

In a cross-sectional study on recreational runners, Junior et al<sup>(24)</sup> found a high incidence rate of 55% for RRI. Two-hundred participants completed an electronic form consisting of personal demographic information, running experience, training characteristics, type of running shoes, foot type and previous history over the past twelve months. The participants in this study had a mean running experience of five years and trained an average of four sessions a week<sup>(24)</sup>.

Other studies have found similar high incidence rates. In a study on experienced collegiate cross-country runners, an incidence rate of 74% was reported <sup>(42)</sup>. The authors relate this high incidence rate to the competitive nature of the sample group. With an average of 12 to 16 races per year, the intensity of the training loads of this group was very high in comparison to other recreational runners <sup>(42)</sup>.

In another study on cross-country runners, lower incidence rates were found. Rauh et al <sup>(43)</sup> studied 393 high school cross-country runners over a season and found 38% reported an injury. A limitation to the study was that other variables such as training characteristics were not taken into account. Also, the coaches at the particular high school reported the RRI and although they were trained in the use of the daily injury report form, the accuracy of the data recorded may be questionable <sup>(43)</sup>.

Lun et al <sup>(44)</sup> studied 153 recreational runners and reported 79% of the participants experienced at least one lower limb injury during a six-month observational period. An injury was defined as any musculoskeletal pain that caused reduction or stoppage of normal training <sup>(39)</sup>. Regular participation in other sports (more than four times per week) was restricted in this study to reduce the influence of injuries from other sports. The participants also had to run more than 20 km.wk<sup>-1</sup> to be included in this study <sup>(44)</sup>. Table 2.1 shows the epidemiology of RRI in the current literature. The level of evidence (LOE) according to evidence based medicine criteria is noted. Level of evidence (LOE) I includes high-quality randomized controlled trial with statistically significant differences, or no statistically significant difference but narrow confidence intervals. Systematic reviews of Level I studies are also referred as LOE I. LOE II refers to lesser quality randomised controlled or prospective comparative studies. Systematic reviews of Level II studies or Level I studies with inconsistent results are also referred as LOE II. LOE III includes case controlled, randomised comparative or retrospective studies. LOE IV refers to case studies. LOE V refers to expert opinion<sup>(45)</sup>.

Table 2.1: Summary of epidemiological studies on running-related injuries.

Reference	Study sample (n)	Study design	Study duration	Definition of running-related injury	Conclusion	LOE
Buist et al <sup>(17)</sup>	Novice and recreational runners (n = 629)	Prospective study	Eight weeks	Self-reported running-related musculoskeletal pain of the lower extremity or back causing a restriction of running for at least one day	25.9% incidence rate of RRI	II
Buist et al <sup>(21)</sup>	Novice runners (n = 532)	Prospective study	13 Weeks	Self-reported running-related musculoskeletal pain of the lower extremity or back causing a restriction of running for at least one week	21% incidence rate of RRI	II
Bovens <sup>(41)</sup>	Novice runners (n = 115)	Prospective study	18 – 20 months	Any physical complaint developed in relation to running activities and causing restriction in running distance, speed, duration, or frequency was considered to be an injury	85% incidence rate of RRI	II
Junior et al <sup>(24)</sup>	Recreational runners with a minimum of 5 yrs. experience (n = 200)	Cross-sectional retrospective Study	12 months follow-up	Any running-related musculoskeletal pain that was severe enough to prevent the runner from performing at least one training session	55% incidence rate of RRI	III
Lun et al <sup>(44)</sup>	Recreational runners (n = 153)	Prospective study	Six months	Any musculoskeletal symptom that causes a reduction or stoppage of normal training	79% incidence rate	III

Table 2.1: Summary of epidemiological studies on running-related injuries continues.

Reference	Study population	Study design	Study duration	Definition of running -related injuries	Conclusion	LOE
Rauh et al <sup>(43)</sup>	Cross-country high school athletes (n = 393)	Prospective cohort study	One cross-country season	A muscle, joint or bone problem/injury of the back or lower extremity resulting from a practice or meet that required the runner be removed from a practice or competitive event or to miss a subsequent practice or competitive event	37% incidence rate Runners with a Q-angle of > 20° had a relative risk (RR) of 1.7	III
Reinking et al <sup>(42)</sup>	Cross-country collegiate runners (n = 88)	Prospective cohort study	One cross-country season	Pain located between the knee and the ankle and occurs during exercise	68% reported a history of ERLP 80.8% reported incidence of ERLP during the current season	III
Taunton et al <sup>(2)</sup>	Recreational runners (n = 844)	Retrospective study	13 weeks	Pain after exercise Pain during exercise Pain during exercise Pain preventing running	29% incidence rate of RRI	III
Daoad et al <sup>(46)</sup>	Experienced endurance runners (n= 52 )	Retrospective cohort study	Not specified	Not specified. Injuries were recorded by medical staff	74% experienced moderate to severe RRI	III

<sup>s</sup> RRI – Running-related injuries, Q –angle – Quadriceps angle, ERLP – Exercise related leg pain

## 2.4 Definitions of running-related injuries

Injury definitions vary considerably throughout the research<sup>(47)</sup>. This may be the reason for the large variants in the RRI incidence rates in the literature. Taunton et al<sup>(2)</sup> defined RRI according to the following grades: *“pain only after exercise (Grade I); pain during exercise but not restricting distance or speed (Grade II); pain during exercise and restricting distance and speed (Grade III); and pain preventing all running (Grade IV)”*. This was a retrospective study on recreational runners in a training clinic. Almost 30% (249 of 844 runners) reported an injury during the thirteen-week study period<sup>(2)</sup>. In other studies on recreational runners, RRI was defined as *“any musculoskeletal symptom of the lower limb that required a reduction or stoppage of normal training”*<sup>(44)</sup>. This definition could result in an incorrect injury being reported as a symptom does not necessarily differentiate between pain and stiffness<sup>(44)</sup>.

In contrast, the studies by Buist et al<sup>(21,48)</sup> described a running-related injury as *“any musculoskeletal complaint of the lower extremity or back causing a restriction of running for at least on week”*. Severity was rated as pain without limitation, pain that restricted running or made it impossible to run through the RRI<sup>(17,21)</sup>. Buist et al<sup>(21,48)</sup> also recorded injury incidence in RRI per 1000 hours of running exposure. These studies were both prospective studies on novice runners. In an earlier study by Buist et al<sup>(17)</sup>, an injury that restricted running for one day was considered a RRI.

In the study on cross-country runners, a RRI was defined as *“a muscle, joint or bone problem/injury of the back or lower extremity resulting from a practice or meet that required the runner be removed from a practice or competitive event or to miss a subsequent practice or competitive event”*<sup>(43)</sup>. The injury incidence rate in this study was 38%. However, these injuries were recorded by coaches and not medical professionals<sup>(43)</sup>.

In another study on cross-country runners a much higher injury rate of 75% was reported. These injuries were all diagnosed by a medical professional<sup>(46)</sup>. Van Middelkoop et al<sup>(11)</sup> studied the risk factors for RRI in marathon runners. Injury was subjectively defined as any self-reported *“injury to muscles, joints, tendons and/or bones of the lower extremities (hip, groin, thigh, knee, lower leg, ankle, foot, and toe) that the participant attributed to running”*<sup>(11)</sup>.

Chorley et al <sup>(19)</sup> defined an injury as *“a musculoskeletal, metabolic, or neurologic disorder/illness that occurred during running training that caused the participant to alter his/her training regimen”* <sup>(19)</sup>. A five- point scale that was based on activity modification was used to measure the severity of the injury. The study population was participants of the Nike Women’s Marathon and thus included mainly experienced female runners. The results of the study found that group training programme participants were significantly more likely to report intra-race injury than non-group training programme runners. Peer pressure, differences in training patterns could have influenced the results of this study<sup>(19)</sup>.

After reviewing the literature, it was decided to use the definition for RRI described by Buist et al <sup>(17,48)</sup> for this current study. The sample population (novice runners) and the study period (eight weeks) were both similar to the current study. Therefore, in this study, a RRI was defined as *“any musculoskeletal complaint of the lower extremity or back causing a restriction of running for at least one week”* <sup>(17)</sup>.

## **2.5 Classification of running-related injuries**

Running-related injuries can be classified as acute/traumatic or overuse injuries <sup>(15,16)</sup>. Acute injuries may be a result of an extrinsic cause such as a direct blow or an internal cause such as a muscle tear or ligament sprain <sup>(4)</sup>. However, most running-related injuries may be classified as overuse injuries <sup>(8,15)</sup>. An overuse injury is termed as *“an injury due to the applied stress that is too high or the recovery time is too short for the tissue of the musculoskeletal system to adapt appropriately”* <sup>(1)</sup>. An overuse injury may be caused by any repetitive activity <sup>(4)</sup>. Training characteristics such as running distance, training intensity, rapid increase in weekly mileage may all contribute to overuse injuries <sup>(16)</sup>. As described by Hreljac <sup>(15)</sup>, an increase in running distance or training intensity would increase the repetitions of the applied stress and increase the likelihood of injury. Other potential risk factors for developing an overuse injury are a history of previous injury and some anatomical factors, but conflicting results have been found in the literature. These potential risk factors will be discussed later in Section 2.8 (page 21).

Novice runners' musculoskeletal system may not be adapted for the high demand of a new training programme and overuse injuries may occur <sup>(15)</sup>. This may be due to a sedentary lifestyle before the start of such a programme or due to the high demand of a new training programme.

This was found in a study by Buist et al <sup>(17)</sup> where no running experience or limited experience was the biggest risk factor in both male and female runners. To prevent these overuse injuries, appropriate advice on frequency, distance, speed and progression is needed for both novice and experienced runners <sup>(15)</sup>.

## **2.6 Types of running-related injuries**

The main injuries seen in runners are tendinopathies and muscle injuries. Junior et al <sup>(24)</sup> studied the characteristics and training habits of 200 recreational runners in a retrospective cross-sectional study. Tendinopathies comprised 17% of the reported injuries and muscle injuries 16%. This was followed by sprains (ligament/joint) 13.6%, plantar fasciitis 12.7%, low back pain 8.2%, meniscus or cartilage injury 8.2% and stress fractures 6%. The average age of the participants was 43 years and most of the study's sample was males (60%) <sup>(24)</sup>. As none of these injuries were diagnosed by a medical professional, the accuracy of the type of injury has to be questionable.

There are various specific running-related injuries and many studies on the incidence rates of these injuries. Section 2.6.1 and section 2.6.2 will discuss these specific running-related injuries and the anatomic site of injuries respectively.

### **2.6.1 Specific running-related injuries**

In a retrospective study on recreational runners, patellofemoral pain syndrome (PFPS) was the most common injury reported in 331 runners <sup>(49)</sup>. This was followed by iliotibial band syndrome (ITBS) (n = 168), plantar fasciitis (n = 158), meniscal injuries (n = 100), tibial stress syndrome (number not mentioned), Achilles tendinopathy (number not mentioned), patellar tendinopathy (n = 96), gluteus medius injuries (number not mentioned), tibial stress fractures (number not mentioned) and spinal injuries (number not mentioned) <sup>(49)</sup>.

Similar results were seen by Schwellnuss & Stubbs <sup>(23)</sup>. In their retrospective cohort study, two groups of runners were studied to evaluate the effect of shoe prescription on the risk of developing a RRI. The experimental group consisted of runners who had undergone a clinical lower limb biomechanical assessment followed by a running shoe prescription. The control group purchased running shoes without undergoing a biomechanical assessment. The study found PFPS (12.0%) to be the most frequently reported injury in the experimental group. This was followed by ITBS (7.2%), shin pain (4.8%), Achilles tendon injury (7.2%), plantar fascial injury (6.0%), and bone stress injury (3.6%). In the control group, ITBS (12.8%) was the most frequently reported injury. This was followed by shin pain (10.6%), PFPS (7.4%), Achilles tendon injury (5.3%), plantar fascial injury (2.1%) and bone stress injury (1.1%). All diagnoses were made by a health professional <sup>(23)</sup>. However, a limitation of this study was the documentation of specific diagnoses for the injuries, relying on the recall of the runner <sup>(23)</sup>.

Other lower limb injuries may be classified as exercise-related leg pain (ERLP). This is often used to classify a regional pain syndrome <sup>(42)</sup>. For example, the pain is located between the knee and the ankle and occurs during exercises. Several pathologies are included in the definition of ERLP, such as medial tibial stress syndrome, chronic exertional compartment syndrome, tibial or fibular stress fractures, tendinopathies (posterior tibialis, anterior tibialis, peroneals and Achilles), nerve entrapment syndromes, and vascular syndromes <sup>(42)</sup>. Reinking et al <sup>(42)</sup> conducted a prospective cohort study on collegiate cross-country athletes to determine the extrinsic and intrinsic risk factors for ERLP. The navicular drop test, medial longitudinal arch angle, and a visual assessment of the foot type were recorded, as well as a pre-season and post-season questionnaire. The questionnaire included information on the number of years of running, training history, gender and injury history. In the study, 68% of the athletes reported a history of ERLP over their running career in the pre-season questionnaire and 38 reported the incidence of ERLP during the current season. There was a significant relationship between the seasonal incidence of ERLP and a history of ERLP, but no relationship between ERLP and foot measurements <sup>(42)</sup>.

In the literature, in many cases RRI were not diagnosed by a health professional. RRI were often only classified according to the anatomical site of the injury <sup>(2)</sup>. The following section will discuss the anatomical site of RRI.

## 2.6.2 Anatomical site of running-related injuries

Running-related injuries affect mainly the lower extremities <sup>(8,9,18)</sup>. Systematic reviews determined the predominant site of lower limb running injuries is the knee <sup>(8,9,15)</sup>. Epidemiological data of other common sites of injury were the lower leg (shin, Achilles tendon, calf and heel) where the incidence ranged from 9% to 32%; foot and toes, where the incidence ranged from 66% to 39%; and the upper leg (hamstring, thigh and quadriceps), where the incidence ranged from 3% to 38% <sup>(9)</sup>.

Buist et al <sup>(18)</sup> reported 37% of injuries in novice runners occurred at the knee. Similar results were seen by Taunton et al <sup>(2)</sup> in their study on novice and recreational runners. The most common site of injury was the knee (33.7%). The following sites of injury were also reported: the shin (15.2%); foot (13.2%); calf and Achilles tendon (10.0%); ankle (10.4s%); hip and pelvis (9.2%); lower back (5.6%); hamstring (2.4%); and thigh (0.8%). These injuries were self-reported, as well as those diagnosed by a health professional. This may have increased the accuracy of the data and the location of the injury <sup>(2)</sup>. According to Junior et al <sup>(24)</sup> the high rate of knee injuries may be due to the increase in impact force that increases by one-and-a-half to three times the body weight when running. In their cross-sectional study, they found 27% of injuries occurred at the knee <sup>(24)</sup>.

In contrast, Van Middelkoop et al <sup>(11)</sup>, found the most common area of injury was the calf (30.3%), closely followed by the knee (29.1%). The study population was experienced male runners who were training for a marathon. The injuries were reported the month leading up to or during the marathon. There was an interesting correlation between running distance and calf injuries. A training distance less than 40 kilometres (km) per week was a strong protective factor of future calf injuries <sup>(11)</sup>.

Rauh et al <sup>(43)</sup> reported the shin (42.2%) to be the most prevalent injury amongst cross-country runners. Lun et al <sup>(44)</sup> observed the foot (15%) to be the most common injury in 87 recreational runners. Lun et al <sup>(44)</sup> also found a difference in the location of injury between genders. The most common injuries in males were the knee (13%), followed by the hip and foot (10%). In the female runners, the most common injuries were to the foot (15%), followed by the thigh and lower leg (9%) respectively <sup>(44)</sup>.

## **2.7 Risk factors for running injuries**

Many intrinsic and extrinsic variables have been implicated in the development of RRI but there is little consistency about the causes of RRI <sup>(21)</sup>. Intrinsic factors refer to factors in the human body and extrinsic to environmental factors <sup>(5)</sup>. Intrinsic factors include age, gender, anthropometry, biomechanics and previous injuries. The main extrinsic factors for running injuries are overuse or incorrect training <sup>(15)</sup>. Other extrinsic factors, such as running shoes, surfaces, and participation in other sports have also been identified as possible risk factors <sup>(8,9,15,21,23,50)</sup>.

Most studies conclude that risk factors for injuries are multifactorial and should be looked at holistically <sup>(8)</sup>. For that reason, well-controlled randomised studies identify the possible risk factors accurately. In the literature, however, few well-controlled studies exist <sup>(16)</sup>.

### **2.7.1 Intrinsic factors**

As previously mentioned, intrinsic factors that have been implicated in RRI are age, gender, anthropometry, biomechanical variables, running experience, and previous injury. These factors will be discussed in the following section.

#### **2.7.1.1 Age**

Taunton et al <sup>(2)</sup> found age to be an intrinsic risk factor for RRI in female runners. This prospective study on RRI in training clinics found female runners over the age of 50 years had an increased risk for overall injury. Being a female runner below 31 years of age was a protective factor against a new injury. In this large study sample (n = 844), 635 participants were female and 11.5% were over the age of 50 years. This is in contrast to other studies that have found an increase in age as a protective factor <sup>(9,24)</sup>. However, this decrease in risk might not be due to the result of the aging process but rather because the experience of the runner will help them to avoid possible compromising training habits <sup>(10)</sup>.

Age can play a role in the type of tissue involved and area affected by injury. In a recent study, ankle injuries accounted for 31.4% of all RRI in school-aged children <sup>(51)</sup>. Sprains and strains were the most common type of injury in adolescents 15- to 18-years-old and one-third of RRI injuries involved a fall <sup>(51)</sup>. Master runners (that is, above the age of 40 years) are seen to have more soft tissue injuries to the calf, Achilles and hamstring areas <sup>(9)</sup>. Few studies have looked prospectively at the relationship between age and RRI in novice runners. Our study looks at the relationship between age and RRI in novice runners.

### **2.7.1.2 Gender**

Males and females runners have different risk profiles <sup>(21)</sup>. Taunton et al <sup>(49)</sup> found a statistically significant difference between gender in certain injuries. Being less than 34 years of age was a risk factor for developing ITBS, patellar tendinopathy and tibial stress syndrome in males <sup>(49)</sup>.

Satterthwaite et al <sup>(52)</sup> also found a difference between genders and the anatomical site of injury. The results showed males were more prone to hamstring and calf injuries, while females were at increased risk of hip injuries. The study population in Satterthwaite's study was, however, limited to marathon runners and the injuries were sustained during an actual marathon. The competitive nature of the study's sample could have influenced the outcome of this study <sup>(52)</sup>.

Female athletes are at greater risk for stress fractures, with some studies showing double the incidence rate compared to males <sup>(53)</sup>. This was also found in the study by Taunton et al <sup>(49)</sup>, where females with a BMI of less than 21 kg.m<sup>-2</sup> were at a significantly higher risk for tibial stress fractures and spinal injuries. The female triage (osteoporosis, amenorrhea, and anorexia) may cause this difference in the risk profile <sup>(5)</sup>. Patellofemoral syndrome and shin splints have also been found to be more common in female military recruits <sup>(54)</sup>. Rauh et al <sup>(54)</sup> had a 7.5% incidence rate of PFPS and 7.2% shin splints in the study sample after only 13 weeks of basic training. The large study population (n = 748) and standard training programme, surface, and footwear improved the level of evidence (LOE I) for this study. Their results showed an increased Q-angle (> 20°), which may contribute to the increasing incidence of either PFPS and / or shin splints in female athletes <sup>(54)</sup>.

This difference in injury risk profile and anatomical site of injury between genders, might be explained by the differences in lower extremity alignment found between male and females<sup>(55)</sup>. Nguyen & Shultz<sup>(55)</sup> found that females had greater anterior pelvic tilt (pelvic angle), femoral internal rotation (hip anteversion), knee hyperextension (genu recurvatum), and knee valgus (standing quadriceps angle and tibiofemoral angle) compared to males. They found, however, no differences in navicular drop, tibial torsion or standing rearfoot angle<sup>(55)</sup>. The sample population of this study was healthy college students. Our study looks at the relationship between gender and RRI in novice runners.

### **2.7.1.3 Anthropometry (BMI)**

According to the American College of Sports Medicine (ACSM) guidelines, the body mass index (BMI) is used to assess weight relative to height<sup>(3)</sup>. This is done by dividing the body weight in kilograms by height in meters squared ( $\text{kg}\cdot\text{m}^{-2}$ ). The normal BMI for both males and females is 18.6 to 24.9  $\text{kg}\cdot\text{m}^{-2}$ <sup>(3)</sup>. Values of 30 and above are considered obese<sup>(3)</sup>.

Buist et al<sup>(12)</sup> did a study on 848 non-injured novice runners preparing for a 4-mile (6.7km) running event. The primary outcome was RRI per 100 participants. The results showed 25% of the overweight participants (BMI > 25) sustained a RRI compared to 15% in the non-overweight group (BMI < 25). This was a significant finding with  $p = 0.03$ . In this study, all runners also completed an orthopaedic examination prior to the start of the programme. In contrast Taunton et al<sup>(2)</sup> found a BMI greater than 26  $\text{kg}\cdot\text{m}^{-2}$  was a protective factor for injury in male runners<sup>(2)</sup>. According to the authors, this might be due to the lack of regular training in these individuals and not to the BMI itself<sup>(2)</sup>.

As previously mentioned, female runners with a BMI of less than 21 $\text{kg}/\text{m}^2$  are at greater risk for developing tibial stress fractures and spinal injuries. Chorley et al<sup>(19)</sup> found females starting a marathon training programme were more likely to be underweight<sup>(19)</sup>. In the same study, male athletes were more prone to be obese<sup>(19)</sup>. There is inconclusive evidence that a high or low BMI is associated with running-related injuries<sup>(9,16)</sup>. In this current study, BMI was assessed to determine the risk for developing a RRI in novice runners.

#### 2.7.1.4 Quadriceps angle

Studies have found that a significant correlation between an increased quadriceps or Q-angle, greater knee abduction and hip adduction angle may play a role in the aetiology of PFPS<sup>(15)</sup>. Differences between genders have been reported, with females having a larger Q-angle<sup>(54,56)</sup>. The normal values for the Q-angle are  $15.8^{\circ} \pm 4.5^{\circ}$  for females and  $11.2^{\circ} \pm 3.0^{\circ}$  for males<sup>(56)</sup>. The hypothesis is that a greater or excessive Q-angle will influence the running kinematics by increasing the rearfoot eversion or subtalar pronation. However, in a study on non-injured subjects the only correlation with an increased Q-angle was an increase in time to maximum tibial internal rotation<sup>(56)</sup>.

According to the authors, the impact of this single factor on producing knee injury is unknown. This study was conducted on 32 healthy individuals and 3-dimensional kinematic data were collected from the right lower limb<sup>(56)</sup>.

Runners with a Q-angle of more than  $20^{\circ}$  were found to be at greater risk of injury in the study on high school cross-country runners. The relative risk (RR) was 1.7 times greater (95% confidence interval) compared with runners whose Q-angle was  $10^{\circ} - 15^{\circ}$ . This study consisted of a large study population ( $n = 393$ ). However, it might not be representative of all runners as it was done on cross-country runners with an age limit of 13 to 19 years, which might have influenced the results.

Other studies have also found similar results in runners but small study populations were used in those studies<sup>(16,57,58)</sup>. Because these studies were retrospective, cause and effect was difficult to determine. It is possible that these risk factors might actually be the result of the running injury rather than an actual cause of the injury<sup>(16)</sup>.

Lun et al<sup>(44)</sup> showed no correlation between static alignment and injury. In their study, they evaluated 87 athletes during a six-month period. Static alignment tests, including the Q-angle test, were done prospectively. Although the injury rate was 79%, there was a low incidence of a specific injury. The most common injury was patellofemoral syndrome<sup>(44)</sup>.

The relationship between the Q-angle and injury has thus not been consistently observed in research. The static assessment of the Q-angle might contribute to this, as it does not take into account the motion of the tibia and femur respectively during running<sup>(59)</sup>. Our study looks at the relationship between the Q-angle and RRI in novice runners.

### **2.7.1.5 Foot pronation**

Excessive pronation has been implicated as an intrinsic risk factor for overuse RRI <sup>(15)</sup>. The initial stance phase or foot strike is facilitated by the actions of the subtalar joint which causes pronation of the foot <sup>(60)</sup>. In a study on female marathon runners, the velocity of pronation was associated with patellar tendinopathy <sup>(61)</sup>. This may lead to earlier tibial internal rotation which subsequently puts more strain on the anterior knee area <sup>(61)</sup>. This study showed that it is not necessarily the amount of pronation or internal rotation that leads to pathological changes, but rather the velocity of these actions <sup>(61)</sup>.

Reinking et al <sup>(42)</sup> studied collegiate cross-country athletes and found that there was no association with exercise-related leg pain (ERLP) and foot type <sup>(42)</sup>. Foot type was defined as pronated, neutral or supinated. In this prospective study, three validated measurements were taken, the navicular drop test, medial longitudinal arch angle, and visual assessment of the foot. A limitation of the study was that the study population was small (n=88), not representative of all runners, and that the tests were all static. It has to be mentioned that the ERLP was self-reported and other risk factors, such as participation in other sports, were not assessed.

According to the systematic review by Cheung and Ng <sup>(62)</sup> there is no direct evidence between excessive rearfoot pronation and PFPS. Their systematic review looked at the link between PFPS, running shoes and lower leg biomechanics. A total of 42 articles were screened and most of these studies were undertaken on experienced runners <sup>(62)</sup>. Few studies have examined the relationship between foot pronation and RRI in novice runners. For that reason, the navicular drop test was included in this current study.

### **2.7.1.6 Hamstring flexibility**

Hamstring injuries are common in running and have a high recurrence rate <sup>(14)</sup>. Risks for hamstring injuries include previous injury, muscle imbalance, poor flexibility, and muscle fatigue <sup>(63)</sup>. In a study on 136 professional footballers, unilateral hamstring stiffness and leg stiffness were measured in the month before the competitive season to assess if pre-season stiffness was related to injury occurrence. Players who sustained a hamstring injury during the season recorded significantly higher mean hamstring stiffness (11%,  $p=0.04$ )<sup>(64)</sup>.

Similar results were found in runners. Hreljac et al <sup>(65)</sup> compared a group of injured runners and a group of runners who had been injury free during their running career. The injury-free group demonstrated significantly greater posterior thigh (hamstring) flexibility, as measured by a standard sit and reach test <sup>(65)</sup>. However it is recognised the role of the hamstring differs between endurance runners and explosive sports. No prospective studies on hamstring flexibility in novice runners were found, and therefore a review of hamstring injuries in different sports has been included. Caution is thus needed when interpreting these findings in relation to endurance runners. Our study looks at the relationship between hamstring flexibility and RRI in novice runners.

### **2.7.1.7 Muscle power**

Endurance running improves muscle strength and performance over time <sup>(4)</sup>. Paavolainen et al <sup>(33)</sup> researched the effect of explosive strength training in 22 male cross-country runners. In this study, the total training volume was kept the same in both groups, but 32% of training in the experimental group and 3% in the control group was replaced by explosive-type strength training. A 5-km time trial, running economy, maximal 20-m speed ( $V_{20m}$ ), and 5-jump tests were measured on a track. After nine weeks of training, the results showed an improvement in the 5 km time trail in the experimental group <sup>(33)</sup>.

However, endurance training may cause a decrease in maximum voluntary strength after a long, dynamic exercise session <sup>(66)</sup>. Bentley et al <sup>(66)</sup> examined fourteen healthy endurance athletes. Lower limb recovery of muscle force-generating capacity was measured at rest, as well as at six and 24-hours respectively following a bout of cycle exercise. The analysis of lower limb recovery of muscle force-generating capacity included a 6 s cycle test, a maximal isokinetic leg extension at 60, 120 and 180°.s<sup>-1</sup>, and a maximal concentric squat jump. A significant reduction in isokinetic peak torque at 60°.s<sup>-1</sup> was found after six hours of recovery <sup>(66)</sup>. This decrease in muscle strength may predispose runners to sustain a RRI if there was no adequate recovery after a long training session <sup>(66)</sup>. The relationship between muscle power and RRI in novice runners was investigated in our study.

### 2.7.1.8 Balance

Low balance ability is significantly associated with increased risk of ankle injuries <sup>(67)</sup>. Willems et al <sup>(68)</sup> studied the balance ability in physical education students and found a relationship between low balance ability and subsequent injury. However, there was no correlation between ankle injuries and balance in female students. Participants were asked to do the Flamingo balance test which requires participants to stand on one leg while balancing on a beam <sup>(68)</sup>. It is not a dynamic balance test which could affect the clinical implications.

The Star Excursion Balance Test (SEBT) is a functional performance test of the lower extremity and is used to assess chronic ankle instability <sup>(69)</sup>. In a recent study, Endo & Sakamoto <sup>(69)</sup> studied the relationship between lower limb tightness and the SEBT performance in basketball players. Thirty-three male basketball players participated in the study. Four directions, namely anterior, medial, posterior and lateral, were used to measure the balance of the participants. Hip external and internal rotation, hamstring, quadriceps and gastrocnemius muscle range of motion were also measured. The study found a significant correlation between lower limb tightness and decreased balance <sup>(69)</sup>. Even though the study was on basketball players, runners could also be affected by muscle tightness and subsequently, decrease balance. For this reason, the SEBT was included in this current study in order to determine the correlation between balance and RRI.

### 2.7.1.9 Running experience

Running experience has been implicated as a risk factor for RRI <sup>(1,2)</sup>. Novice runners may not have adapted to the stress running places on the musculoskeletal system <sup>(1,17,18)</sup>. This correlates with a recent study on recreational runners <sup>(24)</sup>. In this study, it was found that running experience of more than five years was predictive of a lower risk for running injuries. This correlation might be due to the “*survival phenomenon*”<sup>(11,52)</sup>, because the most experienced runners are the ones that survive from injury <sup>(24)</sup>.

Van Middelkoop et al <sup>(11)</sup> also found a correlation between experience and injury recovery. A positive trend between running experience of more than ten years and recovery from an injury was found in this study on marathon runners <sup>(11)</sup>. Experienced runners might have a lower incidence rate of injury but can have persistent complaints of pain.

Van Middelkoop et al <sup>(11)</sup> found that 25.5% of male runners training for a marathon complained of pain at three-month follow-up intervals. <sup>(11)</sup>. Experienced runners might thus be more use to some degree of discomfort or pain but do not necessarily stop or decrease training time or mileage <sup>(11)</sup>. As our study focus on novice runners, previous running experience was not investigated in this study.

#### **2.7.1.10 Previous injury**

A history of previous musculoskeletal injury is a very strong predictor for RRI <sup>(8)</sup>. Recurrence of running injuries is reported in 20% to 70% of the cases <sup>(10)</sup>. The definition of previous injury is, however not well defined in the literature <sup>(17)</sup>. Previous injury might refer to previous “*running*” injuries or it may refer to any type of injury. This might affect the outcome of the studies and should be considered when applying it to clinical practice <sup>(17)</sup>.

Taunton et al <sup>(2)</sup> found 42% of runners starting in a training clinic programme were not fully rehabilitated after a previous injury. In a large prospective study in the United States of America, 35% of runners starting a new training programme still experienced pain from a previous injury <sup>(19)</sup>. As most runners aim for a specific distance or have a race in mind, starting a programme with pain may alter the outcome of such a training programme and/or the results.

Buist et al <sup>(18)</sup> found males with a previous injury had an odds ratio of 2.6 for re-injury. This correlates with an older study which had an odds ratio for injury of 2.7 for habitual runners with a previous injury in the past year <sup>(70)</sup>. However, Buist et al <sup>(18)</sup> found no correlation with previous injury and RRI in female runners. According to the researchers, this might be as a result of the high number of new female runners who may never have previously run on a regular basis <sup>(18)</sup>.

In particular, the hamstring muscle has been implicated as a high risk for re-injury. Studies have shown that previous injury to the hamstrings is a high predictive factor for further injury <sup>(14)</sup>. Hamstring strain injuries are extremely common in sport, and effective treatment and rehabilitation still remains a big challenge <sup>(71)</sup>. A high hamstring injury rate of 30% has been found in some previous studies <sup>(71)</sup>. MRI imaging and biomechanical assessments have been undertaken on subjects with previous hamstring injuries and a significantly enlarged proximal biceps femoris volume was measured.

This, however, did not affect strength measurement, peak hamstring stretches, or muscle activations, but the possibility of residual scar tissue may contribute to the high rate of re-injury in the hamstrings <sup>(71)</sup>. Due to the high correlating factor between a history of previous injury and RRI, the relationship in novice runners was also assessed in our study.

## **2.7.2 Extrinsic factors**

Extrinsic risk factors are external factors which have an impact on the body <sup>(4,15,16)</sup>. These include training volume, frequency, duration, intensity, participation in other sporting activities, training surface, and shoes <sup>(15,16)</sup>. Hreljac & Ferber <sup>(15)</sup> found that 60% of running-related injuries are due to training errors. As running is a far more complex and coordinated process than walking, an increase in stress on the body can result in a higher risk of injury <sup>(60)</sup>. Running increases weight-bearing on joint surfaces and can influence the kinetic chain, or alter the biomechanics <sup>(60)</sup>. These altered movements can cause repetitive stress on joints, tendons or muscles which can lead to an inflammatory response <sup>(25)</sup>. Specific extrinsic factors, such as training methods, surface, shoes and participation in other sports <sup>(8,9,15,21,23,50)</sup>, will be discussed in the following sections.

### **2.7.2.1 Training methods**

Research has found that between 60% and 70% of running injuries are due to training errors <sup>(15,47)</sup>. A training programme should be designed to stress the body at an appropriate level to gain the required benefits, without resulting in injury <sup>(5)</sup>. If most RRI are overuse injuries, then it may be suggested that most injuries are preventable <sup>(15)</sup>.

With the correct training intensity and duration, the musculoskeletal system would be able to adapt to the demand. Training design can be divided into distance (km), duration (min), intensity, and frequency <sup>(47)</sup>. Our study looked at the relationship between distance, intensity and frequency and RRI risk in novice runners.

#### **2.7.2.1.1 Distance and duration**

Running distance usually refers to the distance the runner completes on a daily basis. Training distance may be one of the strongest contributors to RRI <sup>(9,10,15)</sup>. Training distances of more than 20 miles (32 km) per week have been associated with an increased risk of injury <sup>(47,70)</sup>. Walter et al <sup>(22)</sup> found an increase in relative risk amongst male runners with a weekly mileage more than 40 miles (64 km) per week. Walter et al <sup>(22)</sup> also found a significant increase in relative risk if the longest run of the week was more than 5 miles (8 km).

Similar results were seen in a study on military recruits. Rudski et al <sup>(72)</sup> found a significant decrease in injury incidence in military recruits when running distance was reduced and substituted with walking intervals. The intervention period was 12 weeks with a mean of 41.3 hours of running per week. The training distance was greatly reduced from 280 km to 82 km over 12 weeks <sup>(72)</sup>. Bovens et al <sup>(41)</sup> found that as the distance increased over time (18 months) from 15 miles (24km) to 37 miles (60km) per week, the risk of injury was reduced. This reduction in injury risk can be explained as the runners became more experienced during the 18 months of training. It has to be noted that the runners in the study by Bovens et al <sup>(41)</sup> followed a supervised training programme which also might have resulted in the decrease in injury risk.

Other studies following a graded training programme for the first two weeks showed no significant difference in prevention of injuries <sup>(18,73)</sup>. Buist et al <sup>(18)</sup> implemented the “10% rule” in the 13-week intervention group. The study was a well-designed randomized controlled trial with an appropriately calculated sample size, an adequate follow-up period, and a low number of dropouts. In their study, a 13-week programme of graded training for novice runners did not result in fewer running-related injuries than a standard eight-week programme. According to the authors, a possible reason for this result may be due to the inability to control the training intensity, thus suggesting that it might not be the load that increased the running-related injury risks but rather the intensity. Bredeweg et al <sup>(1)</sup> found similar results when they compared a four-week pre-conditioning programme into a controlled nine-week running programme.

In this study, both groups showed a relatively low RRI incidence (16%). No significant differences were found between the two groups. The incidence of RRI was 15% in the pre-conditioning group and 17% in the control group. The self-reporting of RRI might have influenced the recall bias of this study <sup>(1)</sup>.

Training duration refers to the time a runner trains per session. It is usually measured in minutes. In a 20-week study, training times of 15 to 30 minutes were found to reduce the risk of injury compared with 45 minutes of training per day <sup>(73)</sup>. However, the study participants were only male runners between the ages of 20 to 35 years, which may not be representative of the general running population.

#### **2.7.2.1.2 Intensity**

Buist et al <sup>(18)</sup> found no correlation between a graded training programme and the incidence of RRI. The authors suggested that the development of a RRI may be due to training intensity and not necessarily due to the training distance <sup>(18)</sup>. Training intensity may be altered by increasing the speed of a training session <sup>(5)</sup>. Increased running speeds produce greater forces on the related musculoskeletal structures which may increase the risk for overuse injuries <sup>(15)</sup>. Gabbett & Ullah <sup>(74)</sup> investigated running speed as a possible risk factor for soft tissue injuries. The sample consisted of elite rugby players and the running speed and distances were calculated by means of a GPS over one season (November 2010 to September 2011). A total of 117 training sessions, which lasted between 60 and 100 minutes were analysed. They found a very interesting correlation between high velocity running and injury. Players who covered greater distances at very low intensities/speeds had a lower relative risk for soft-tissue injury. An increase in relative risk for injury was found in players with greater amounts of high-velocity running (sprinting) <sup>(74)</sup>. This sample group consisted of elite, team sport athletes. However, these findings suggest that it may be important to assess training intensity as a risk factor for RRI in novice runners.

#### **2.7.2.1.3 Frequency**

Running frequency refers to the number of days a runner trains per week <sup>(2)</sup>. Taunton et al <sup>(2)</sup> found an increase RRI risk in females who only ran once a week. They concluded that if a runner does not build a base during regular training sessions per week, the risk of injury increases.

The study population was limited to specific “In training” clinics, and thus all participants should have followed a graded training programme during the 13-week intervention <sup>(2)</sup>. Similar results were found in marathon runners <sup>(11)</sup>. Van Gent et al <sup>(9)</sup> found regular interval training a strong protective factor for knee injuries.

A systematic review by Yeung and Yeung <sup>(73)</sup> looked at the relationship between training frequency and RRI. The review determined that runners who had trained for more than three days per week were at an increased risk of injury. This may have been due to the lack of adequate rest and the musculoskeletal system not adapting to the high demand<sup>(73)</sup>.

Nielsen et al <sup>(47)</sup> described in another systematic review that it is difficult to determine the effect of frequency on injury due to the conflicting research, as one study found an increase risk in female runners training one time per week compared to other studies that reported an increase risk amongst runners training more than six to seven times per week. Therefore, cumulative distance might be a better indicator of injury risk than the lack of rest day in between training days <sup>(47)</sup>.

### **2.7.2.2 Running shoes**

Runners are often given advice regarding which are the best running shoes to purchase. Shoe retailers advise and assess up to 70% of runners on foot types and type of running shoes <sup>(24)</sup>. Motion control shoes are recommended to presumably control excessive pronation, while cushioned shoes allow more pronation and shock absorbency for rigid or inflexible feet <sup>(23)</sup>. Stability shoes are recommended for average-arched individuals <sup>(23)</sup>. However, there is limited evidence linking shoes to actual cases of RRI. Knapkin et al <sup>(75)</sup> found that prescribing running shoes on static, weight-bearing plantar shape is not an effective method for preventing running injuries. The study participants were military recruits during nine-week basic combat training and only looked at plantar shape. No other tests were used to determine foot motion and alignment <sup>(75)</sup>.

A randomised controlled study by Schwellnuss & Stubbs <sup>(23)</sup> studied the effect of a clinical lower limb biomechanical assessment and RRI. Although this was a retrospective study and the injuries were self-reported, other confounding risk factors were all taken into account.

No significant differences were found between the injured and uninjured groups with regards to height, gender, type of running shoes, stretching habits and running surface. They concluded that the advice health professionals give to runners regarding the purchase of running shoes should be revised and other extrinsic factors have to be taken into consideration for RRI<sup>(23)</sup>. Barefoot running has been advocated to reduce the risk of running injuries<sup>(76)</sup>. Most barefoot runners are forefoot strikers<sup>(60)</sup>. Runners who habitually run with shoes, tend to land on the heel at footstrike<sup>(60)</sup>. At footstrike, the foot will absorb approximately three times the body's weight and it is argued that forefoot landing tends to help to absorb this impact<sup>(60)</sup>.

Daoud et al<sup>(46)</sup> concluded in their study on collegiate cross-country runners that rearfoot strike runners were 2.6 times more likely to suffer from a mild injury and 2.4 times more likely to have moderate injuries compared to forefoot strikers (FFS). Running severity intensity scores (RISS) were used to calculate the severity of the injury. A probable reason for this decrease in incidence rate may be due to the decrease in load with FFS running. However, FFS runners might have an increased risk of Achilles tendinopathy or calf muscle strains because of the higher stress placed on the posterior structures<sup>(46)</sup>. In the current study, running style or shoe type will not be assessed but a question regarding running shoes formed part of the questionnaire.

### **2.7.2.3 Environment / Surface**

Running surface and plantar load have been associated with sport injuries<sup>(77)</sup>. Recreational and marathon runners commonly run on concrete or asphalt surfaces. Other surfaces are natural grass or synthetic rubber tracks<sup>(77)</sup>. Studies have shown that impact forces associated with repetitive loading may be responsible for overuse injuries in the lower limb<sup>(15)</sup>. Wang et al<sup>(77)</sup> evaluated 15 experienced runners (weekly mileage > 20 km), measuring plantar load while running on natural grass, concrete and synthetic rubber respectively. All participants had no injury history for six months prior to the study and each was given a pair of the same type of running shoe. The hypothesis that the plantar load was less on natural grass was supported in the study. They found a significant difference between impact on natural grass and concrete especially with regard to the lateral midfoot and the central and lateral forefoot. According to the researchers, this may be explained by the adjustment in the distal extremity's stiffness<sup>(77)</sup>.

The same was found in a larger study population of both sexes (n=47) <sup>(78)</sup>. Tessuti et al <sup>(78)</sup> also found that grass produced 16% less peak pressures at the rearfoot and lateral foot. More compliant surfaces may decrease the stress on the musculoskeletal system and lower the risk of injury <sup>(78)</sup>. This may be beneficial for novice runners to reduce the impact on the musculoskeletal system.

Treadmill running is often considered as a useful training method due to convenience, sociology and climate reasons <sup>(77)</sup>. However, research has shown that as stride length is decreased, stride rate increases and the period of non-support is less when running on a treadmill than when running over ground <sup>(79)</sup>.

Milgrom et al <sup>(79)</sup> did a study to determine tibial strains and the strain rate during treadmill running compared to over ground running. By measuring the tibial strain in vivo they found that over ground running had significantly higher compression strain rates compared to treadmill running. The substantially higher tibial strain and strain rate indicates that over ground runners are at a higher risk of tibia stress fractures than treadmill runners <sup>(79)</sup>.

Our study did include a question regarding to training surface to determine the relationship between surface and RRI in novice runners.

#### **2.7.2.4 Participation in other sports**

Van Middelkoop <sup>(11)</sup> found that more than half (58%) of runners participate in other sports while training for a marathon. Similar results were seen in novice runners enrolled for a training programme <sup>(18)</sup>. Cross-training has been suggested to decrease the risk of injury in runners. This decrease can be explained by possible strength imbalances that are corrected by cross-training. Non-axial (non-weight-bearing) activities, such as swimming or cycling, can also replace some of the weekly mileage for runners. This may decrease some of the impact that contributes to RRI <sup>(2)</sup>.

However, the opposite was found in a study by Nielsen et al <sup>(13)</sup>. In their study on 930 novice runners, male runners had a 2.1 higher risk for developing RRI if they previously participated in non-axial loading sports. Adaption of the musculoskeletal system to loading is attributed to the lower risk in axial loading sports <sup>(21)</sup>.

The same was found with a study on marathon runners where cycling was implicated in an increased risk for thigh and hamstring injuries. This might be as a result of the high demand being placed on the thigh muscles during cycling activities <sup>(19)</sup>.

These conflicting results regarding participation in other sports and RRI in the literature indicate that further research is necessary. In this study, the association between participation in other sports and RRI will be investigated.

## **2.8 Instrumentation**

Physical testing may identify potential risk factors for RRI. Most musculoskeletal tests include strength, flexibility, agility and power tests <sup>(80)</sup>. In this study on novice runners, both dynamic and static tests are included. The Q-angle, navicular drop, active knee extension, star excursion balance test (SEBT) and vertical jump test were performed prior to the start of an eight-week training programme.

### **2.8.1 Q-angle test**

The Q-angle is the resultant pull of the quadriceps muscle on the patella and the tibial tuberosity <sup>(60)</sup>. It is measured by drawing a line from the anterior superior iliac spine to the centre of the patella, and a second line from the centre of the tibial tubercle to the centre of the patella. The angle where these lines intersect is regarded as the Q-angle <sup>(81)</sup>. It is suggested that an excessive Q-angle increases foot pronation or rearfoot eversion and could result in an increase in tibial internal rotation <sup>(81)</sup>. These increases in rearfoot eversion and tibial internal rotation have been implicated in the development of knee injuries in runners as this causes a torsional load on the tibiofemoral joint <sup>(81)</sup>.

In a systematic review by Smith et al <sup>(81)</sup>, conflicting results were found in the literature regarding the reliability and validity of the Q-angle test. Intratester reliability ranged from poor (ICC 0.22) to almost perfect agreement (ICC 0.81). The same was found with intertester reliability. These conflicting results may be due to differences in testing procedures. Variables such as patient position (supine or standing) and whether the quadriceps should be contracted or relaxed were found in the literature <sup>(81)</sup>.

Due to the high incidence of knee injuries in runners, the Q-angle still remains an important factor in risk assessment in runners. Therefore the Q-angle test was included in this study to determine the possible link between RRI and novice runners.

### **2.8.2 Navicular drop**

Pronation and supination form an integral part in the kinematics of running. The navicular drop test measures the amount of subtalar joint pronation <sup>(82)</sup>. This was assessed by measuring the change in the height (mm) of the navicular tuberosity between a participant seated with the subtalar joint in the neutral position and a participant standing with the subtalar joint in a weight-bearing position <sup>(83)</sup>. Subtalar neutral is when talar depression is equal on both medial and lateral side of the ankle. Normal values in the adult population range from 6 mm to 9 mm, with abnormal values in excess of 13 mm <sup>(55)</sup>. Mueller et al <sup>(82)</sup> conducted a study to investigate the reliability and validity of the navicular drop. They concluded that a navicular drop of more than 10 mm was abnormal. They also reported that intratester reliability ranged from 0.78 to 0.83 supporting the validity of the navicular drop test as a measurement of foot pronation <sup>(82)</sup>.

### **2.8.3 Active knee extension test**

The hamstring muscle group has a complex role during the running cycle <sup>(60)</sup>. It has been described as a stabilizer for the knee during the loading phase as well as eccentrically decelerating the lower leg during the swing phase <sup>(60)</sup>. It also acts as a stabilizer for the lumbar-pelvic region and contributes to whole body stability <sup>(14)</sup>. A decrease in hamstring flexibility has been shown to increase the risk for injury <sup>(14)</sup>. Hamstring flexibility can be measured with the active knee extension (AKE) test. The AKE test can be performed by a single assessor and has shown excellent interrater and intrarater reliability (ICC 0.92) <sup>(63)</sup>. A limitation with the AKE test is the ability of the patient to maintain 90° hip flexion during the test <sup>(84)</sup>. To assist in maintaining hip flexion during the AKE test, a 90° angle board was used in this study to improve the accuracy of the test.

#### **2.8.4 Vertical jump test**

Lower limb muscle weakness has been associated with RRI<sup>(9,15)</sup>. The vertical jump test is designed to test leg power in an individual. This test is performed from a squat position with the knees flexed to approximately 90°. A jump up to reach maximum vertical height is measured in centimetres. A coefficient of variation (CV) value of 3.3% for the vertical jump has been found, particularly in studies that may produce small but important changes in athletic performance<sup>(85)</sup>.

Burnstein et al<sup>(80)</sup> found a 96% intra-class correlation (ICC) using the drop-step technique. Other studies have also shown a high reliability while some of the other power tests required expensive force platform equipment<sup>(80)</sup>. For that reason, the vertical jump test is cost-effective and not very time consuming. In this study, a bilateral barefoot vertical jump from a stationary position was used to assess leg power.

#### **2.8.5 Balance test**

Balance is defined as the ability to maintain the body's centre of gravity over a base of support<sup>(67)</sup>. In a systematic review, Hrysomallis<sup>(67)</sup> found five out of nine prospective studies proved a decrease in balance increased the risk of ankle or lower limb injury in athletes. However, none of these studies' participants were runners. There are a variety of tests to determine balance, but few have high reliability and/or validity.

Burnstein et al<sup>(80)</sup> found poor reliability with the dynamic balance test using a high-density foam balance pad and participants had their eyes closed. The Star Excursion Balance test (SEBT) showed a high ICC (0.78 to 0.96) in a study on healthy individuals<sup>(86)</sup>. The SEBT requires the individual to balance on one leg while reaching with the opposite leg to the side, forward and backwards<sup>(87)</sup>. The purpose of the SEBT is to maximally disturb the equilibrium and then return to the starting position<sup>(87)</sup>. Fewer directions in the SEBT are recommended to improve intratester reliability<sup>(86)</sup>. For this reason, in this current study on healthy novice runners the SEBT was assessed in five directions, namely anterior, medial, lateral, posterior medial and posterior lateral.

## 2.8.6 Session rate of perceived exertion

Session rate of perceived exertion (sRPE) scale is a rating of the overall difficulty of the exercise bout, obtained 30 minutes after the completion of the exercise <sup>(29)</sup>. Research found a significant correlation between rate of perceived exertion (RPE) and heart rate<sup>(88)</sup>. The rate of perceived exertion may be used to accurately estimate exercise intensity <sup>(29)</sup>.

A recent study on sprint kayak athletes compared three different scales of perceived exertion with common methods of training load <sup>(89)</sup>. Training load was quantified for external (distance and speed) and internal (session-RPE: 6-20, category ratio [CR]-10 and CR-100 scales, training impulse , and individual)<sup>(89)</sup>.

Ten junior sprint kayak athletes were monitored for seven weeks. Moderate-to-large inverse relationships were found between mean session-RPE and various aerobic fitness variables (-0.58 to -0.37). Large to very large relationships were found between mean sRPE and on-water performance (0.57 to 0.75). The study concluded sRPE is a valid method for monitoring training load in sprint kayak athletes as it relates to fitness and performance <sup>(89)</sup>. Similar results were seen in a study on water polo athletes <sup>(90)</sup>. Thirteen young male water polo players were monitored over eight training sessions. Session RPE was obtained using CR-10 scale and the Edwards summated heart-rate-zone method was used a reference measure of internal training load (ITL). The results confirmed that the session-RPE method as an easy and reliable tool to evaluate ITL in youth water polo <sup>(90)</sup>. The rating scale for sRPE that was used in this study is shown in Table 2.2.

Table 2.2: Session RPE (modified from Lambert & Borreson <sup>(29)</sup>)

Rating	Description
0	Rest
1	Really easy
2	Easy
3	Moderate
4	Sort of hard
5	Hard
6	
7	Really hard
8	
9	Really, really hard
10	Just like my hardest race

## 2.9 Summary of the literature

Running is a growing sport in many countries <sup>(21,25)</sup>. Benefits of running include cardiovascular fitness, strength and endurance <sup>(6)</sup>. Running might even lower the risk for developing hypertension <sup>(6)</sup>, diabetes, cancer and other diseases-of-lifestyle<sup>(5,31)</sup>. However, the negative effects of running also need to be taken into consideration when starting a running programme. Negative effects of endurance running include: exercise-induced muscle damage (EIMD), delayed onset muscle soreness (DOMS), overtraining, acute kidney injury and running-related injuries (RRI) <sup>(4,6,9,15,18,29)</sup>.

Running is associated with a high incidence of injuries, and incidence rates of 24% to 90% have been reported <sup>(8,16,18)</sup>. The variation in incidence rates may be attributed to differences in study designs, definitions of RRI, and study samples <sup>(16)</sup>. Running-related injuries may be classified as acute or overuse injuries <sup>(15,16)</sup>, with overuse injuries accounting for the majority of RRI <sup>(8,15)</sup>. Common types of RRI include tendinopathies and muscle injuries<sup>(2,9,17)</sup>, and the knee was identified as the most common site of injury in the majority of studies <sup>(8,16,47)</sup>.

Current research has examined both intrinsic and extrinsic factors for RRI but the results are still very inconclusive. It is evident that there are numerous risk factors associated with RRI, and that the aetiology of RRI may be multifactorial and diverse <sup>(15)</sup>. However, most studies on RRI are retrospective and it is therefore difficult to determine whether intrinsic and extrinsic factors are causative or contributing <sup>(18)</sup>. In addition, few studies have prospectively examined the predictors for injuries in novice runners <sup>(8,16,17)</sup>. With running experience being inversely related to the incidence of injuries <sup>(8)</sup> it is important to establish why novice runners may be more at risk of RRI. Therefore, an improved understanding of risk factors for RRI in novice runners is required.

## **Chapter 3: Risk factors for lower limb musculoskeletal injuries in novice runners**

### **3.1 Introduction**

Running has become an increasingly popular sport worldwide <sup>(8,18,21)</sup>. Many health benefits are associated with running <sup>(5,6,31)</sup>. However, running is associated with a high incidence of musculoskeletal injury, which may both limit current participation and prevent future participation in the sport <sup>(8,15)</sup>. Most of these are musculoskeletal injuries to the lower limb, and may include acute and overuse injuries <sup>(9,15)</sup>. There are multiple factors that contribute to RRI, and both intrinsic and extrinsic factors may contribute to the development of acute or overuse RRI <sup>(15)</sup>. It is postulated that novice runners might be more at risk of developing RRI due to the unaccustomed loading of the lower limb musculoskeletal system that is associated with running training <sup>(18)</sup>. However, there is limited evidence regarding the incidence of RRI in novice runners, and the associated risk factors for RRI.

Accordingly, the aim of this study was to prospectively evaluate the risk factors associated with the development of RRI in novice runners. The specific objectives of this study have been described in Section 1.2 (page 2).

### **3.2 Methods**

#### **3.2.1 Research design**

This study has a descriptive, prospective, longitudinal design.

#### **3.2.2 Recruitment of participants**

Healthy male and female novice runners were recruited for this study from local running clubs and health clubs in Port Elizabeth, Eastern Cape. Participants were recruited through word of mouth and through a study advertisement that was emailed to all running clubs in Port Elizabeth (Appendix I). Participants were also recruited at study information sessions presented at two local running clubs.

### **3.2.2.1 Inclusion criteria**

Participants were included in the study if they were between the ages of 18 and 45 years and novice runners. A novice runner was defined as “a runner who had not been running on a regular basis in the previous 12 months”<sup>(21)</sup>. Regular running was defined as running more than 10km of the total running volume in all training sessions during the past year<sup>(13)</sup>. Participants who took part in other recreational activities were also included, as long as this did not comprise more than 4 hours per week<sup>(13)</sup>.

### **3.2.2.2 Exclusion criteria**

Participants who reported any relevant medical or surgical history were excluded from the study. Participants were also excluded if they reported any history of musculoskeletal pathology or injury to the lumbar spine or lower limbs in the three months prior to the commencement of the study. Participants were also excluded if any medical concerns were detected during the health and physical activity screening. Those participants who were unwilling to keep a training logbook for eight weeks were excluded.

### **3.2.3 Sample size calculation**

Data from a previous prospective study of running injuries<sup>(2)</sup> were used to ensure that the sample size would provide sufficient statistical power. Running frequency was selected as the main risk factor for the determination of the required sample size. Required sample size for running frequency was calculated using a smallest relative risk of 3.6, an injury incidence of 25%, and a prevalence of exposure of 50%. With statistical significance accepted as  $p < 0.05$ , groups of 30, 40 and 49 participants provided 80%, 90% and 95% statistical power for running frequency respectively. Forty-two participants were recruited for this study to ensure sufficient statistical power, in case some participants were unable to complete the study.

### **3.2.4 Group allocation**

Due to the prospective nature of this study, all participants entered the study as uninjured, novice runners. For data analysis, participants were allocated to injured and uninjured groups at the end of the study. Participants were allocated to the injured group if they reported a RRI during the eight-week training period of this study. Participants were allocated to the uninjured group if they did not report a RRI during the eight-week period of this study.

## **3.3 Measurement instruments**

### **3.3.1 Informed consent form**

All participants were required to fill in an informed consent form (Appendix II) prior to the commencement of testing. All relevant information relating to the study and the description of the physical testing to be undertaken were provided. The risks and benefits to the participants were described and the participant's right to withdraw from the study at any time was discussed. The protection of participant's privacy and how confidentiality of data would be maintained were also explained in the informed consent form.

### **3.3.2 Physical Activity Readiness Questionnaire (PAR-Q)**

Participants completed the modified Physical Activity Readiness Questionnaire (PAR-Q) (Appendix III). The PAR-Q was used to screen participants for safe participation in physical activity. If any medical conditions were identified, participants were excluded from the study and referred for appropriate medical attention.

### **3.3.3 Medical and running history questionnaire**

A self-designed medical, injury and running history questionnaire (Appendix IV) was completed after participants had given their written informed consent. The questionnaire was used to obtain information regarding the participants' demographics, medical and surgical history, injury history and running history.

The questionnaire was developed by the researcher and study supervisors. The questionnaire was then reviewed by a panel of two experts (a sports physician and a sports physiotherapist) with specific interest in RRI to ensure content and construct validity. The validators were contacted after ethical approval was granted and the questionnaire was emailed to them. The validators were asked to comment on the clarity and ease of understanding of the questionnaire; and to recommend any additions necessary to improve the content and construct validity of the questionnaire. The majority of feedback received from the validators was related to the formatting of the questionnaire, and the order of presentation of the questions. These recommendations were included and the questionnaire was adapted before being completed by the participants in the feasibility study (Section 3.3.8, page 49).

### **3.3.4 Familiarisation session**

All participants underwent a familiarisation session prior to the anthropometric measurements and the musculoskeletal test. This was done on the day of recruitment or on the day of testing, depending on the availability of the participants. The participants were familiarised with the testing protocols that would be used during the musculoskeletal tests. This was to ensure that the participants understood the requirements of the study, and also to minimise any error associated with participants performing unaccustomed exercises.

### **3.3.5 Anthropometry**

Body mass and stature measurements were assessed to calculate body mass index (BMI). Body mass (kilograms) (kg) was recorded using a calibrated scale (Slimguide skinfold collection model: FAB12-1125), with an accuracy of 0.1kg.

Stature (cm) was recorded using a stadiometer (Seca model, 206 Germany) with an accuracy of 1mm. Body mass and stature were assessed with participants barefoot, and wearing shorts and a T-shirt. Body mass index (BMI) was calculated according to the formula used by the Centre for Disease Control ([http://www.cdc.gov/healthyweight/assessing/bmi/adult\\_bmi/metric\\_bmi\\_calculator/bmi\\_calculator.html](http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/metric_bmi_calculator/bmi_calculator.html)).

### **3.3.6 Musculoskeletal tests**

The musculoskeletal tests that were performed in this study were the quadriceps angle test, the navicular drop test, the active knee extension test for hamstring flexibility, the vertical jump test, and the Star Excursion Balance Test. All tests were performed with participants barefoot, and wearing shorts and a T-shirt.

#### **3.3.6.1 Quadriceps angle (Q-angle) test**

Participants were asked to stand erect against a wall while the Q-angle measurements were taken. The participants were asked to keep the quadriceps muscles relaxed during the measurements. The anterior iliac spine, centre of the patella and tibial tuberosity were identified by palpation and marked with a pen. Using a tape measure, a line was drawn from the anterior iliac spine to the centre of the patella. The line was extended past the centre of the patella. A second line was drawn from the centre of the patella to the centre of the tibial tuberosity. The angle formed between the two lines was measured with a goniometer as the Q-angle. Three measurements were taken, and the average was recorded. A Q-angle of more than 20° in females and 15° in males is defined as excessive according to the American Orthopaedic Association <sup>(56)</sup>.

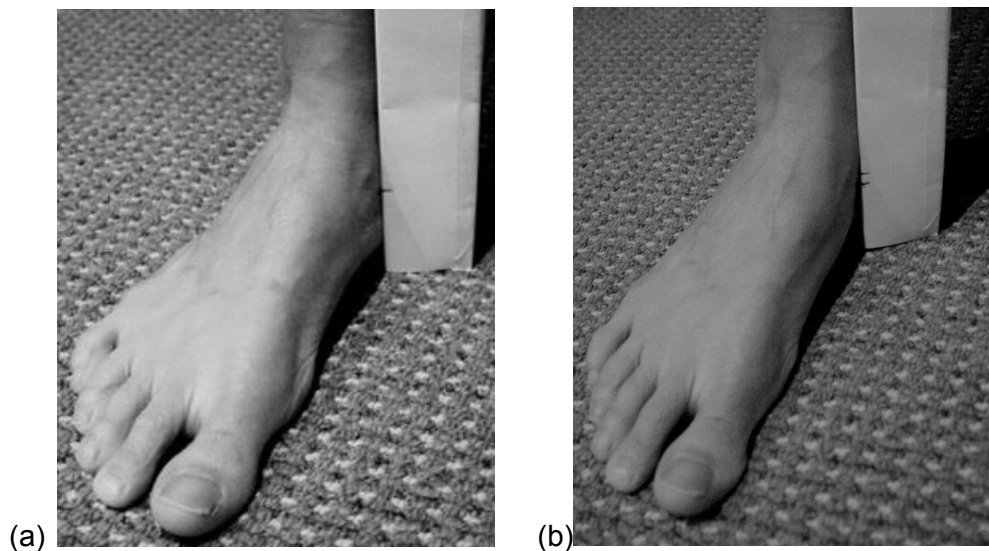
#### **3.3.6.2 Navicular drop test**

The navicular drop test was performed to assess the degree of foot pronation. This was assessed by measuring the change in the height (mm) of the navicular tuberosity between participants seated with the subtalar joint in a neutral position; and participants standing with the subtalar joint in a weight-bearing position <sup>(18)</sup>. The navicular drop test is shown in Figure 3.1. Neutral alignment was obtained by ensuring forward foot

position on a flat surface. Subtalar neutral is achieved when talar depression is equal on both the medial and lateral sides of the ankle <sup>(82)</sup>.

A pen mark was made at the most prominent point of the navicular tuberosity. A piece of white paper was held adjacent to the medial arch and a line was drawn from the height of the navicular tuberosity to the floor in the seated and standing positions. The markings on the white paper were measured with a ruler in millimetres. The differences between the seated and standing measurements were recorded.

Three measurements were taken, and the average was recorded. Normative mean values in the adult population have been reported as 6 mm to 9 mm, using similar measurement methods <sup>(55)</sup>.



*Figure 3.1: Navicular drop test. Line is drawn at the navicular tuberosity with (a) the participant seated and (b) the participant standing.*

### **3.3.6.3 Hamstring flexibility**

Hamstring flexibility was assessed using the active knee extension (AKE) test. Participants were positioned supine on a plinth. The researcher marked the centre of the right knee joint axis over the lateral joint line. Lines were drawn from the knee joint's axis to the greater trochanter of the femur and the apex of the lateral malleolus. Participants were asked to place their right leg over a stabilising board to maintain 90° hip flexion. The stabilising board consisted of two vertical bars and a horizontal bar. The leg was placed with the hip in 90° flexion and the knee was flexed

over the horizontal bar. The contralateral leg was strapped with Velcro straps to maintain the pelvis in a neutral position. Participants were then instructed to actively extend their right knee, while keeping their right foot relaxed in plantarflexion.

The endpoint was reached when participants subjectively reported a strong but tolerable stretch sensation in their hamstring muscle. The angle of knee extension was recorded using a standard goniometer. The centre of the goniometer was positioned over the axis point on the lateral joint line of the knee and the goniometer arms were positioned along the femoral and fibular lines.

Three measurements were taken, with a rest period of one minute between each measurement. Both legs were tested, and an average of three measurements was recorded for each leg. The reliability and validity of the AKE has been previously established <sup>(91)</sup>.

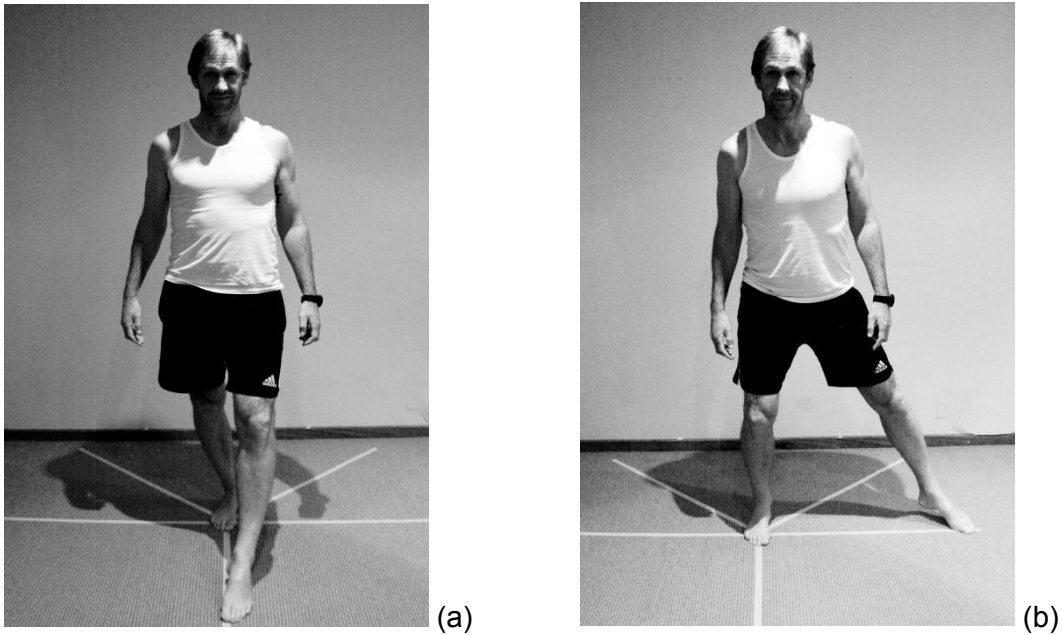
#### **3.3.6.4 Vertical jump test**

A bilateral, barefoot vertical jump from a stationary squat position was used to determine high-speed muscular power of the lower limbs. Standing reach height was measured with participants standing 15 cm side-on against a wall and extending the arm closest to the wall maximally above the head. Participants were not allowed to lift their heels off the ground during this measurement. The maximal height on the wall was marked with red talcum powder from the participant's fingertips. Standing reach height (cm) was measured with a tape measure. Before each jump, participants were verbally encouraged to jump as high and straight as possible. Participants had their dominant hand painted with red talcum powder to ensure their maximal vertical jump height was recorded on the wall. Participants were instructed to initially perform the downward countermovement by flexing their knees and hips, without a preparatory step, bringing their trunk forward and downward, and swinging their arms backwards. This downward countermovement prior to upward propulsion is the eccentric phase of the stretch-shortening cycle, which enables maximum jump height. This was followed immediately by the concentric portion of the jump movement, where participants were instructed to jump as high as possible by extending their knees and hips, and swinging their arms forwards and upwards. At the highest point in the jump, participants reached up with their dominant hand and placed a second powder mark on the wall. The use of arms during take-off was permitted, but no shuffling on the feet was allowed.

Muscle power was reflected as the difference between the standing reach height and the vertical jump height. The vertical jump test was performed three times, with a two-minute rest period between tests. The maximum jump height was recorded. The reliability and validity of the vertical jump test has previously been established <sup>(85)</sup>.

#### **3.3.6.5 Dynamic balance test**

The Star Excursion Balance Test <sup>(86)</sup> was performed to assess dynamic balance. Two lines were marked out on the floor in the shape of a cross, with the lines perpendicular to each other. Two further 45° diagonal lines between the horizontal lines and the back vertical line were marked. Participants were asked to stand upright with one leg in the middle of the star pattern. Participants were then instructed to reach out as far as possible with the big toe of other leg along each of the lines in the following order: anterior, anterior 45° to the left and right respectively, posterior, and posterior 45° to the left and right respectively (Figure 3.2). Participants were required to touch each line with their big toe at the point of their maximal reach. Participants were required to maintain the maximal reach position for five seconds without losing their balance, and then to return to the upright position. The distance from the starting position to the maximal reach position was recorded along each line. If participants were unable to keep their balance or touched the floor at any other point during the reach or return movements, the measurement was discounted and participants were required to repeat that direction of the test again. Three repetitions were allowed. Dynamic balance ability was recorded as the sum of the six reach distances. The star excursion test was performed three times, and the average dynamic ability was recorded for each leg. The reliability and validity of the Star Excursion Balance Test has previously been established <sup>(86)</sup>.



*Figure 3.2: The Star Excursion Balance Test. This figure shows the participant performing the test in (a) anterior and (b) lateral positions.*

### **3.3.7 Daily logbook**

Participants were asked to keep an electronic or manual daily logbook of their training over an eight-week training period (Appendix V). Each participant followed their own individual training during the eight week period. The logbook contained a record of training information, the session rate of perceived exertion (RPE) and any running-related injuries during this period. The logbook was kept electronically but participants who did not have access to the internet or if preferred, were able to fill in the logbook manually. Compliance for the eight week training period was monitored via email or short message service (SMS) every week.

#### **3.3.7.1 Training information**

The daily record of training information included daily mileage (km), the duration of training sessions, the running surface, and type of training session (for example, interval or speed training).

### 3.3.7.2 Session rate of perceived exertion

The overall difficulty of each training session was assessed using a session RPE. This scale translated the participant's perception of effort into a numerical score. After each training session, participants were asked to rate their session RPE within 30 minutes of completing each session according to the question "*How hard was your workout?*" Participants rated their session RPE on a numerical scale from 0 to 10, where 0 reflected an RPE equivalent to "*rest*", and 10 reflected an RPE equivalent to "*just like my hardest race*"<sup>(29)</sup>.

### 3.3.7.3 Running-related injuries

Injury incidence (% of running injuries) was assessed in the eight-week study period by recording the daily occurrence of any running-related injury (RRI). A RRI was defined as "*a self-reported running-related musculoskeletal (muscle, joint or bone) pain of the lower limb (i.e. buttock, hip, thigh, knee, calf, ankle, foot) causing a restriction of running*"<sup>(21)</sup>. Participants were required to document the occurrence of any RRI at the end of each training session. The area and pain intensity of the injury of the RRI were recorded. The areas were defined as the lower back, hip, front or back of thigh, knee, calf, ankle or foot respectively. The visual analogue scale (VAS) was used to determine the pain associated with the injury. Participants rated their pain intensity on a numerical scale from 0 to 10, where 0 reflected "*no pain*" and 10 reflected "*severe pain*"<sup>(92)</sup>. The number of training days that were missed as a result of each RRI were also recorded (Appendix V).

### 3.3.8 Feasibility study

A feasibility study of the medical and running history questionnaire, anthropometric measurements and musculoskeletal tests was conducted prior to the main research study to determine the feasibility of the questionnaire and all physical testing procedures. A sample of convenience was used, and five runners who met the inclusion criteria for the study took part in the feasibility study. No changes were made to the medical and running history questionnaire after completion of the feasibility study. The data from the participants in the feasibility study were not included for analysis.

### **3.4 Study procedure**

Ethical approval was granted by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (Appendix VI). Before the start of the eight-week training programme, all participants gave written informed consent (Appendix II) for the study, and completed the PAR-Q (Appendix III), and medical and surgical questionnaire (Appendix IV). Participants were familiarised with all procedures prior to the commencement of testing. The musculoskeletal assessment included the Q-angle test, the navicular drop test, the AKE test, the Star Excursion Balance Test, and the vertical jump test. All musculoskeletal assessment tests were conducted before the start of the training period and the researcher explained the use of the training logbook during the session. Daily training information and running-related injuries (RRI) were documented in the logbook for an eight-week training period (Appendix V).

### **3.5 Statistical analyses**

Data were analysed using Statistica Software (StatSoft, Inc. 2004. STATISTICA, Data Analysis Software System, Version 11, [www.statsoft.com](http://www.statsoft.com)). Differences in descriptive variables and training history between the injured and uninjured group were assessed using an independent t-test. Previous medical and surgical histories, as well as general sports activities, were assessed using Chi-squared tests and frequency tables. Forward stepwise regression analyses were used to assess whether any descriptive, training, or biomechanical characteristics were predictive of a RRI. Forward stepwise analyses were performed using IBM SPSS Statistics (version 21, 2012). Three different models (descriptive, training and biomechanical models) were developed, and the coding of independent variables is shown in Table 3.1. All variables were entered simultaneously, and the odds ratio (Exp(B)), p-values, 95% CIs and the Wald test were recorded for each of the analyses. The Wald test is used to test the significance of the variable based on the sample estimate. All numeric data are presented as the mean  $\pm$  standard deviation (SD). Categorical data are presented as number of responses and percentages. Statistical significance was accepted as  $p < 0.05$ .

Table 3.1: Predictors variables coded for forward stepwise regression analyses.

Variable	Binary code 0	Binary code 1
<b>Descriptive model</b>		
Age (years)	≤ 39	> 40
BMI (kg.m <sup>-2</sup> )	≤ 25	> 25
Gender	Male	Female
Injury history	No	Yes
Participation in other sports	No	Yes
<b>Training model</b>		
Cumulative training distance in 8 weeks (km)	≤ 100	> 100
Total number of training days in 8 weeks (d)	≤ 24	> 24
Total number of rest days in 8 weeks (d)	≥ 24	< 24
Average training session distance (km)	≤ 45	> 5
Average training session duration (min)	≤ 20	> 20
<b>Biomechanical model</b>		
Q-angle (°)	≤ 14.9 (male) ≤ 19.9 (female)	> 15 (male) > 20 (female)
Navicular drop (mm)	6-9	< 6-9 > 6-9
Active knee extension test (°)	≥ 145	< 145
Dynamic balance (cm)	≥ 240	< 240
Vertical jump (cm)	≥ 30	< 30

### 3.6 Ethical considerations

The study was performed in accordance with the principles of the Declaration of Helsinki (Seoul version, 2008<sup>1</sup>). The study was approved by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (HREC REF: 260/2012) (Appendix VI).

<sup>1</sup> The researcher is aware that there is a new version of the Declaration of Helsinki (Brazil, 2013); however, the current research was conducted prior to the release of the 2013 version.

Ethics approval was obtained prior to the commencement of any research-related activities. Participants were required to give written informed consent (Appendix II) before taking part in the study.

### **3.6.1 Potential risk to participants**

There was a risk of musculoskeletal injury in this study due to the physical nature of the testing. Participants underwent a familiarisation session prior to testing to reduce the risk of injury. All tests were carefully explained, and participants were also instructed to discontinue physical tests if they experienced any discomfort. Participants were also at risk of injury related to their participation in training for endurance running. If participants sustained a RRI, they were referred to an appropriate health practitioner for evaluation and treatment if necessary.

### **3.7 Benefits to participants**

All participants received an information booklet (Appendix VII) after completing the eight-week study period. The booklet contained information regarding the prevention of RRI and possible warning signs of overtraining. The booklet also contained information regarding proper training methods and stretching advice.

## **3.8 Results**

### **3.8.1 Participants**

Forty-two participants were recruited for this study. All participants were uninjured novice runners at the start of the study. One participant withdrew prior to the musculoskeletal tests due to personal reasons. Therefore forty-one participants (22 females and 19 males) completed this study. After the completion of the eight-week training programme, participants were grouped into injured and uninjured categories for statistical purposes. Fifteen participants formed the injured group. The uninjured group consisted of 26 participants.

### 3.8.2 Descriptive characteristics

The descriptive characteristics of participants are shown in Table 3.2. There were no significant differences in descriptive characteristics between the injured and uninjured groups.

Table 3.2: Descriptive characteristics of participants in the injured (n=15) and uninjured (n=26) groups. Data are expressed as mean  $\pm$  SD.

Variable	Injured (n=15)	Uninjured (n=26)
Age (years)	34.1 $\pm$ 7.6	32.9 $\pm$ 7.4
Mass (kg)	79.3 $\pm$ 14.4	77.1 $\pm$ 16.2
Stature (m)	1.8 $\pm$ 0.1*	1.8 $\pm$ 0.1*
Body mass index (kg.m <sup>-2</sup> )	25.2 $\pm$ 4.1	24.3 $\pm$ 3.6

<sup>s</sup> Please note that stature values for both groups are identical due to rounding values to one decimal place.

### 3.8.3 Previous medical, surgical and injury history

There was a low incidence of previous medical and surgical history in both groups. In the injured group, three participants reported a history of hypertension, asthma or diabetes. In the uninjured group, two participants reported a history of hypertension and hypercholesterolemia. However, all participants were adequately screened for safe participation in exercise prior to the start of the training programme (PAR-Q – Appendix III).

In the injured group, three participants reported a history of previous knee surgery, and one participant reported a history of previous foot surgery. In the uninjured group, one participant reported a history of previous hip surgery. However, no participants reported a recent history (last three months) of previous surgery; therefore all participants were eligible for inclusion in this study.

A high percentage of participants reported a history of previous injury (n = 17). Twelve participants in the injured group and five participants in the uninjured group reported a history of previous injury. Five participants reported a previous history of knee injuries. Three participants reported a history of thigh injuries. Three previous hip injuries and one previous injury to the lumbar spine, foot and ankle were noted.

Multiple sites of previous injuries were reported by three participants. The site of the previous injury was reported in the questionnaire, but the type of injury and the nature of injury, specifically whether it was a previous RRI, were not specified.

### 3.8.4 Participation in other sports

Approximately 50% of participants did not take part in any other sporting activities except running (n = 21). Table 3.3 indicates the general sport activities of participants in the injured and uninjured groups. There were no significant differences between groups for participation in other sporting activities.

*Table 3.3: General sports activities of participants in the injured (n=15) and uninjured (n=26) groups. Data are expressed as numbers (n).*

<b>Sports participation</b>	<b>Injured (n=15)</b>	<b>Uninjured (n=26)</b>
<b>No participation in other sport</b>	7	14
<b>Tennis</b>	0	1
<b>Swimming</b>	2	1
<b>Rugby</b>	1	0
<b>Cycling</b>	1	3
<b>Golf</b>	1	2
<b>Strength training</b>	2	3
<b>Netball</b>	0	1

The frequency of the participation in other sports is summarised in Table 3.4. These training sessions were in addition to running training sessions, and no differences were observed between the injured and uninjured groups.

*Table 3.4: Weekly frequency of training for other sports of participants in the injured (n=15) and uninjured groups (n=26). Data are expressed as numbers (n).*

<b>Frequency of participation</b>	<b>Injured (n=15)</b>	<b>Uninjured (n=26)</b>
<b>Not participating in other sports</b>	7	14
<b>Participation once a week</b>	1	3
<b>Participation twice a week</b>	6	7
<b>Participation more than three times a week</b>	1	2

### 3.8.5 Musculoskeletal screening tests

The musculoskeletal screening tests for participants in the injured and uninjured groups are summarised in Table 3.5. There were no significant differences in any of the musculoskeletal screening tests between the injured and uninjured groups.

Table 3.5: Summary of the musculoskeletal tests of participants in the injured (n=15) and uninjured (n=26) groups. Data are expressed as mean  $\pm$  SD.

Variable	Injured (n=15)		Uninjured (n=26)	
	Left	Right	Left	Right
Q-angle (°)	15.4 $\pm$ 3.2	16.4 $\pm$ 3.6	15.0 $\pm$ 3.0	14.8 $\pm$ 3.0
Navicular drop (mm)	6.7 $\pm$ 1.4	7.1 $\pm$ 2.0	7.7 $\pm$ 2.9	8.5 $\pm$ 2.8
AKE (°)	159.5 $\pm$ 10.7	159.1 $\pm$ 11.0	154.8 $\pm$ 10.2	154.9 $\pm$ 10.2
Dynamic balance (cm)	248.5 $\pm$ 12.7	245.9 $\pm$ 11.6	244.8 $\pm$ 22.3	240.9 $\pm$ 22.6
Vertical jump (cm)	32.7 $\pm$ 6.0		32.7 $\pm$ 7.1	

### 3.8.6 Training characteristics

Participants were required to record training information and session RPE using a daily logbook (Appendix V). The logbook was maintained for the eight-week training period of this study.

#### 3.8.6.1 Cumulative running training characteristics

The cumulative running training characteristics of participants in the injured and uninjured groups for the eight-week training period of this study are shown in Table 3.6. There were no significant differences in cumulative training characteristics between groups.

Table 3.6: Summary of cumulative training characteristics of participants in the injured (n=15) and uninjured (n=26) groups for the eight-week training period of this study. Data are expressed as mean  $\pm$  SD.

Training characteristics	Injured (n=15)	Uninjured (n=26)
Cumulative training distance (km)	129.4 $\pm$ 61.1	102.4 $\pm$ 34.8
Cumulative training duration (hrs)	13.5 $\pm$ 5.6	10.9 $\pm$ 4.1
Total number of training days (d)	25.2 $\pm$ 5.3	21.8 $\pm$ 5.2
Total number of rest days (d)	30.7 $\pm$ 5.4	34.2 $\pm$ 5.2
Average session distance (km)	5.2 $\pm$ 1.9	4.4 $\pm$ 1.1
Average session duration (min)	33.2 $\pm$ 10.2	27.9 $\pm$ 6.4

### 3.8.6.2 Weekly training distance

The weekly training distances of participants in the injured and uninjured groups over the eight-week training period of this study are shown in Figure 3.3. There was a significant main effect between groups over time in weekly running distance ( $F_{(7,273)}=2.25$ ;  $p=0.03$ ), with weekly training distance being consistently higher in the injured group compared to the uninjured group. However, there were no significant interactions identified on further post-hoc analyses. The average weekly training distance for the injured group was 16.9 km  $\pm$  7.6 km, compared to 12.8 km  $\pm$  4.4 km for the uninjured group.

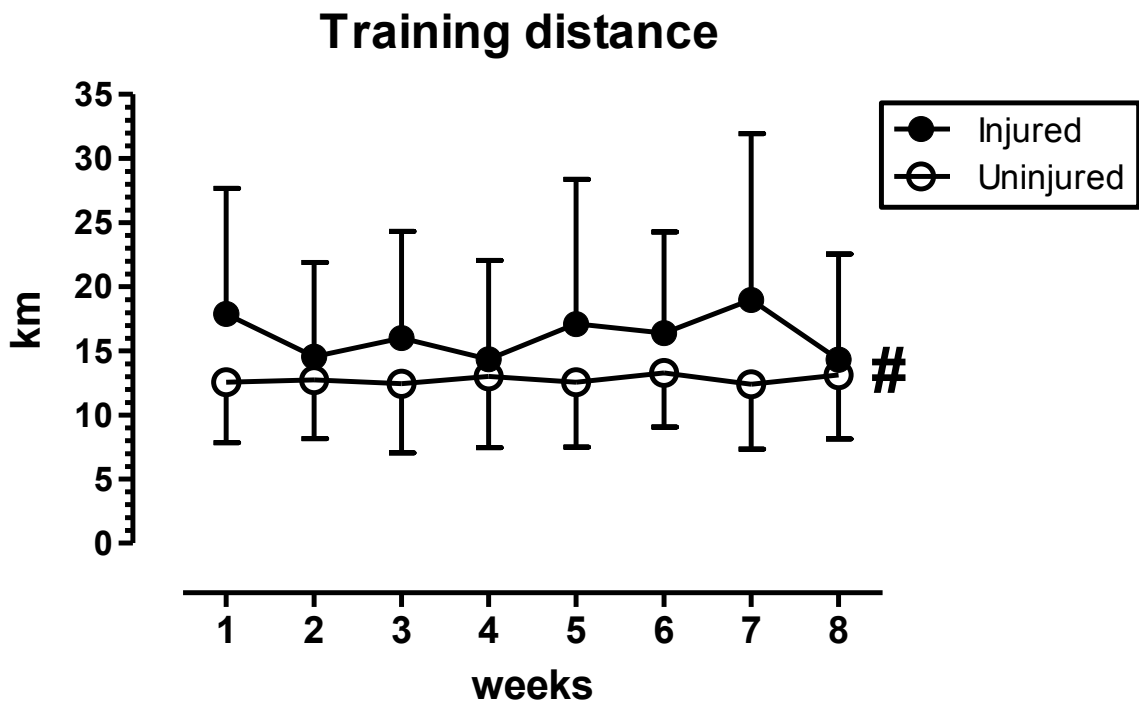


Figure 3.3: Weekly training distance (km) of participants in the injured (n=15) and uninjured (n=26) groups for the eight-week training period of this study. Data are expressed as mean  $\pm$  SD.

Significant differences:

# interaction of group  $\times$  time ( $p=0.03$ )

#### 3.8.6.3 Weekly training duration

The weekly training duration of participants in the injured and uninjured groups over the eight-week training period of this study are shown in Figure 3.4. There was also a significant main effect between groups over time in weekly running duration ( $F_{(7,273)} = 2.05$ ;  $p=0.049$ ), with weekly training duration being consistently higher in the injured group compared to the uninjured group. However, there were no significant interactions identified on further post-hoc analyses. The average weekly training duration for the injured group was 99.4 min  $\pm$  40.7 min, compared to 81.9 min  $\pm$  30.7 min for the uninjured group.

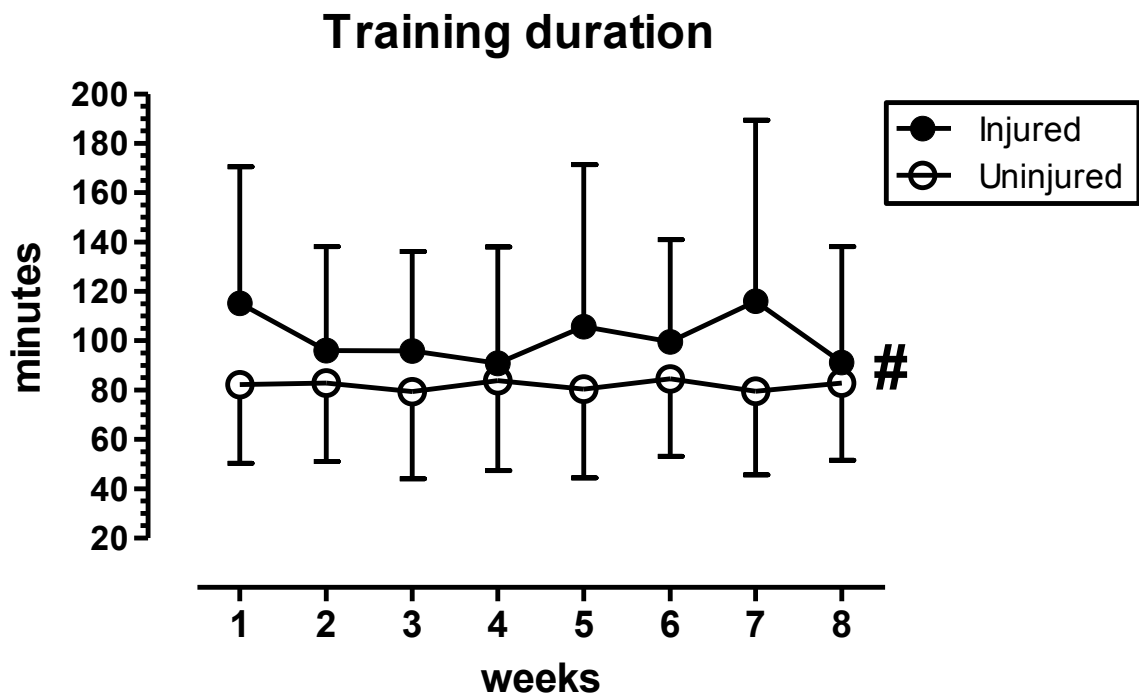


Figure 3.4: Weekly training duration (min) of participants in the injured (n=15) and uninjured (n=26) groups for the eight-week training period of this study. Data are expressed as mean  $\pm$  SD.

Significant differences:

# interaction of group  $\times$  time ( $p=0.049$ )

#### 3.8.6.4 Weekly session RPE

The weekly session RPE of participants in the injured and uninjured groups over the eight-week training period of this study are shown in Figure 3.5. There was a significant main effect between groups over time in weekly session RPE ( $F_{(7,273)}=2.05$ ;  $p=0.049$ ), with weekly session RPE being consistently higher in the injured group compared to the uninjured group. However, there were no significant interactions identified on further post-hoc analyses. The average weekly session RPE for the injured group was  $4 \pm 1$  compared to  $3 \pm 1$  for the uninjured group.

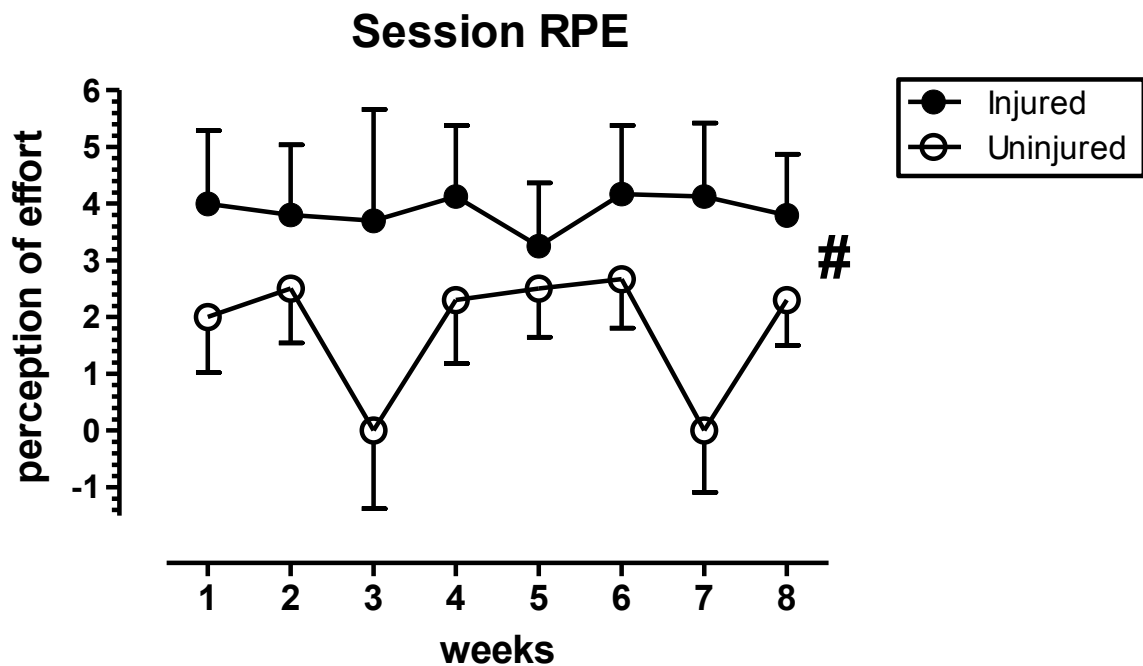


Figure 3.5: Weekly session RPE of participants in the injured (n=15) and uninjured (n=26) groups for the eight-week training period of this study. Data are expressed as mean  $\pm$  SD.

Significant differences:

# interaction of group  $\times$  time ( $p=0.049$ )

### 3.8.7 Running-related injuries

Participants were required to record self-reported RRI in a daily logbook (Appendix V). The logbook was maintained for the eight-week training period of this study.

#### 3.8.7.1 Injury incidence

Fifteen runners (37% of the total sample) reported a RRI during the eight-week training period of this study. Participants in the injured group reported a total number of 20 RRIs. Three participants reported multiple injuries, with one participant reporting four RRIs on different occasions, and the other participants reporting two RRIs respectively. The weekly injury incidence is shown in Figure 3.6. Injury incidence was highest (n=5) in weeks two and six of the eight-week training period.



Figure 3.6: Weekly injury incidence of participants ( $n=15$ ) during the eight-week training period of this study. Data are expressed as numbers ( $n$ ).

#### 3.8.7.2 Injury sites

The knee was the most common site of injury ( $n=11$ ), followed by the calf muscles ( $n=5$ ). The participant who reported four RRIs recorded a knee injury in week one, and a calf injury in weeks five, six and eight. The two participants who reported two RRIs both reported multiple knee injuries. Figure 3.7 shows the injury sites, depicted in a body chart.

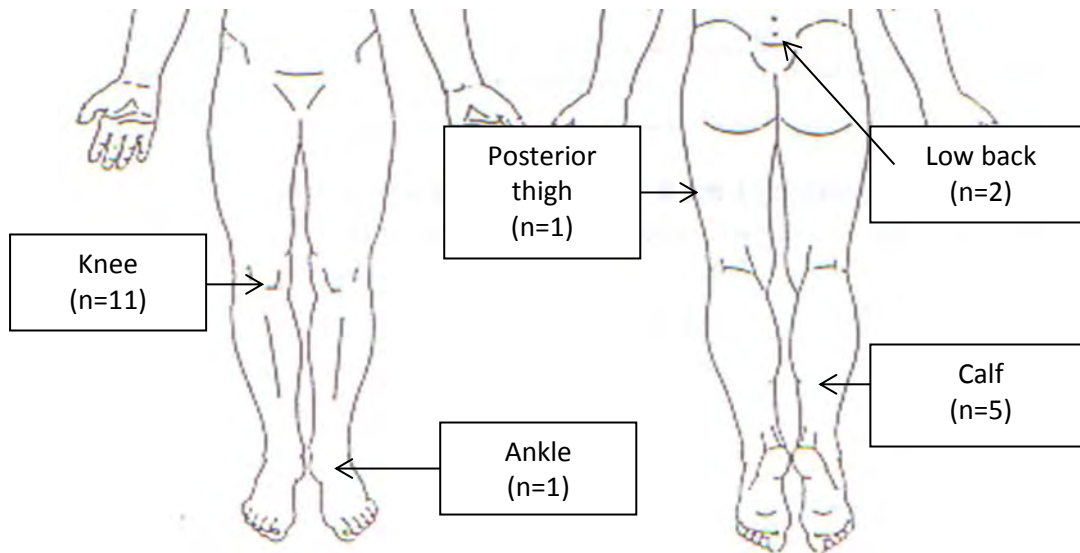


Figure 3.7: Sites of running-related injuries (n=20) sustained during the eight-week training period of this study. Data are expressed as numbers (n).

### 3.8.7.3 Pain associated with injury

The average pain scores associated with RRIs in this study were  $4.0 \pm 1.5$  on the VAS for pain. Participants rested and did not take part in running training for an average of  $3 \pm 4$  days following injury.

One participant received physiotherapy treatment for their RRI and one participant consulted a general practitioner. The majority of participants (n=13) managed their injuries with self-medication. However, the specific pharmacological agents used for self-medication were not recorded.

### **3.8.8 Predictive factors associated with the development of running-related injuries**

Forward stepwise regression analyses were performed to determine potential factors that may be associated with an increased risk of developing a RRI. Descriptive, training and biomechanical covariates were analysed using forward stepwise regression analysis, as described in Section 3.5 (page 51). This study was unable to identify any training or biomechanical factors that were predictive of a RRI. In this study, the only predictive factor that was associated with an increased risk of RRI was a previous history of injury [Exp(B) = 16.8; p=0.001; 95% CI's: 3.4-82.9]. Participants with a history of previous injury were 16.8 times more likely to sustain a RRI, compared to participants without a history of previous injury. However, although injury history was a significant predictive factor, the 95% CIs were very large (3.4-82.9); therefore this finding should be interpreted with caution.

### **3.8.9 Summary of results**

Fifteen participants sustained a RRI during the study period, with a total of 20 RRIs being reported during the eight-week training period. Injury incidence was highest during weeks two and six of the training period. The knee was the most common site of injury. Participants reported mild to moderate pain scores associated with injury, and rested from running training for an average of three days post-injury. The majority of participants (n=13) managed their injuries with self-medication. Weekly training distance and duration, and session RPE were consistently higher in the injured group, compared to the uninjured group, but these differences were not significant. However, participants in the injured and uninjured groups only trained on average  $25 \pm 5$  and  $22 \pm 5$  days over the eight-week study period respectively. The average session training distance and duration for participants in the injured and uninjured groups were  $5.2 \pm 1.9$ km and  $4.4 \pm 1.1$ km; and  $33 \pm 10$  min and  $28 \pm 6$  min respectively. The average session RPE was low to moderate in both groups. There were also no significant differences between groups for any of the musculoskeletal screening tests. This study was unable to identify any training or biomechanical factors that were predictive of a RRI. The only predictive factor that was associated with an increased risk of RRI was a previous history of injury.

In addition, 50% of participants took part in running training only. Those participants who did take part in other sports generally engaged in these activities twice a week. The average BMI was high in both groups, with participants in the injured group classified as overweight, and participants in the uninjured group classified in the upper limit of normal weight <sup>(3)</sup>. Further, 10% of participants (n=4) reported a history of chronic diseases of lifestyle, despite the mean age of both groups being under 35 years of age. These study findings will be discussed in the next section, together with the clinical implications of these research findings. The limitations of the study, as well as recommendations for future research, will also be highlighted.

### **3.9 Discussion**

Running is regarded as a popular form of exercise because of its perceived health benefits and accessibility <sup>(1,2,4,6,17)</sup>. The well-known benefits of running include cardiovascular fitness, strength and endurance <sup>(6)</sup>. However, the incidence rate of RRI has also increased over the past few years. Novice runners have been identified as more at risk for RRI but the risk factors for this group of runners have not been clearly established <sup>(13)</sup>. This study aimed to identify possible risk factors for lower limb musculoskeletal injuries in novice runners, to ensure safe participation in running training programmes. The results of this study will be discussed in the following sections.

#### **3.9.1 Descriptive characteristics**

In this study there were no significant differences between the injured and uninjured groups with regards to age, mass, stature and BMI (Table 3.2, page 53). The mean age for the injured and uninjured groups was  $34 \pm 7$  years and  $32 \pm 7$  years respectively. This correlates with other studies on recreational and novice runners <sup>(2,18,19)</sup>. Taunton et al <sup>(2)</sup> found that most of their participants were between the ages of 31 to 49 years (59%). Chorley et al <sup>(19)</sup> had a similar sample group with the mean age of 36 years. In the study by Nielsen et al <sup>(13)</sup> most of the runners were between 30 to 45 years of age (50.4%). These findings show that runners in their 30s often start a training programme <sup>(2,13,19,21)</sup>, and thus training clinics should consider this age group when developing training guidelines as a means of preventing RRI.

The normal BMI for both males and females is 18.6 to 24.9 kg.m<sup>-2</sup> (3). The average BMI was high in both groups, with participants in the injured group classified as overweight, and participants in the uninjured group classified in the upper limit of normal weight (3). This correlates with other studies on novice and relatively inexperienced runners (2). Buist et al (18) observed that novice runners had a mean BMI of 24.9 ± 3.3 kg.m<sup>-2</sup>. In other studies on experienced runners a slightly lower BMI (24.3 ± 3.9 kg.m<sup>-2</sup>) was found (19). Van Middelkoop et al (11) showed that only 16% of marathon runners had a BMI above 25 kg.m<sup>-2</sup> (11).

Further, 10% of participants (n=4) reported a history of chronic diseases of lifestyle, despite the mean age of both groups being under 35 years of age. There is a lack of evidence for any associations between chronic diseases of lifestyle and RRI in novice or experienced runners, and it is therefore not possible to compare these findings with previous studies. However, the burden of non-communicable diseases (NCD) in South Africa is rising (93) and needs to be considered when giving exercise or lifestyle advice to the public in general, and inexperienced athletes in particular.

The Global Burden of Disease study demonstrated that in Southern Africa, 50% of the causes of morbidity are NCD, with cerebrovascular disease and diabetes ranked in the top 10 (93). A limitation of this study was that the reason for starting the training programme was not asked. This could have potentially influenced runners' training habits, motivation levels, and injury rates. Future studies should determine participants' reasons for commencing running training, and should potentially also monitor changes in risk factors for non-communicable diseases.

### **3.9.2 Training characteristics**

In this study, weekly distance, duration and RPE were all higher in the injured group compared to the uninjured group. These findings are similar to other studies on both novice and experienced runners (2,42). Training errors have been associated with RRI (15), as it affects the applied stress on the musculoskeletal system. In this study, both groups ran relative low mileage, which could have resulted in the incidence rate of RRI to be lower compared to high mileage studies. Training distances of more than 20 miles (32 km) per week have been associated with an increased risk of injury (50). Junior et al (24) observed an injury incidence rate of 55% in 200 runners over a 12-month period, where the average training distance was 35 km.wk<sup>-1</sup>.

In a study on experienced runners with RRI, 30% of runners had training loads of more than 60 km.wk<sup>-1</sup> <sup>(11)</sup>, and more than half of the runners (58%) trained for more than five hours per week.

However, overall training loads and RPE were relatively low. Participants in the injured and uninjured groups only trained on average 25 ± 5 and 22 ± 5 days over the eight-week study period respectively. The average session training distance and duration for participants in the injured and uninjured groups were 5.2 ± 1.9km and 4.4 ± 1.1km; and 33 ± 10 min and 28 ± 6 min respectively. Walter et al <sup>(22)</sup> found no significant difference in relative risk between the reference group who ran less than 10 miles (16 km) per week and the groups who ran distances between 10 and 39 miles (16 and 62.4 km) per week. However, the relative risk of injury was significantly higher among males (2.22 [1.30-3.68]) and females (3.42 [1.42-7.85]) running ≥40 miles (64 km) per week. The average session RPE was low to moderate in both groups. These training loads are low compared to other studies. However, many previous studies required novice runners to train for a specific event, which may explain the differences in training loads. For example, novice runners completing an eight-week training programme in preparation for a 4-mile event (6.4 km) were exposed to 7.1 ± 5.5 training hours per week <sup>(18)</sup>. Although the training distances and durations were low, the running frequency of participants in this study is similar to that of participants in other studies. The participants in the injured group took part in running training on 45% of the available training days during the eight-week training period, or on average, three days a week. In a study of recreational runners, 60% of the runners ran three times a week <sup>(2)</sup>. However, experienced runners tend to train more frequently <sup>(9,11)</sup>, with marathon runners completing five to seven training sessions per week <sup>(23)</sup>.

Furthermore, session RPE was used to measure the intensity of the training session in this study. It was difficult to compare these results to other studies as most studies on novice runners used pace as a measurement of intensity <sup>(47)</sup>. The low session RPE rating in this study might be due to the low training distances and durations, and therefore may not give an accurate reflection of the relative intensity of training sessions. Future studies should include the validation of the session RPE scale and running pace in novice runners.

### 3.9.3 Running-related injuries

#### 3.9.3.1 Injury incidence

Fifteen participants (37%) sustained a RRI during the study period, with a total of 20 RRIs being reported during the eight-week training period. Similar results were found in previous studies on novice runners <sup>(13,17)</sup>. However, it is difficult to draw direct comparisons between this study and previous studies, due to differences in variables such as the study period, the level of experience of the runners, training volumes, and runners being provided with a structured training programme <sup>(2,11,17,18,21,41)</sup>. Bovens et al <sup>(41)</sup> found a much higher incidence rate (85%) of RRI in novice runners, but the higher incidence rate may have been due to the longer study period of 18 to 20 months. In another study, a lower incidence rate (21%) of RRI was observed in novice runners enrolled in a systematic training programme <sup>(18)</sup>. Van Middelkoop et al <sup>(11)</sup> found 54% of runners training for a marathon sustained an injury leading up to a marathon. It is possible that the lower incidence rate in this study may be due to the relatively low training loads during the eight-week study period. Junior et al <sup>(24)</sup> observed an injury incidence rate of 55% in 200 runners over a 12-month period, where the average training distance was 35 km.wk<sup>-1</sup>. Similar results were seen in studies with an increased risk of injury in males with training distances of more than 64 km.wk<sup>-1</sup> <sup>(8,22)</sup>.

During this study, injury incidence was highest during weeks two and six of the training period. Similar findings were observed by Buist et al <sup>(21)</sup>, with the highest incidence of injuries being recorded in week two in a control group of runners who were not taking part in a graded training programme. In this study, although overall training loads were significantly higher over the eight-week study period in the injured group, compared to the uninjured group, there were no differences in weekly training loads. This suggests that the increased injury incidence at week two might be related to novice runners' failure to adapt to training loads <sup>(15)</sup>.

Alternatively, the novice runners may have experienced exercise-induced muscle damage and DOMS, due to exposure to unaccustomed exercise. It is possible that the symptoms of DOMS, which include stiffness, soreness, and tenderness <sup>(4,37)</sup>, might have been misinterpreted as a musculoskeletal injury.

However, this study did not investigate runners' pain experiences in sufficient depth to be able to determine whether this occurred. Future studies should clearly differentiate between the symptoms of DOMS and the possible symptoms of RRI. Our study also observed an increase in injury incidence in week six of the eight-week study period. This increase in injury incidence might be due to possible fatigue as a result of repetitive loading in the preceding training weeks. This correlates with other studies which found an increase in injury or illness when the training loads are higher than the athletes' training threshold <sup>(74,94)</sup>.

### **3.9.3.2 Area of injury**

As in previous studies <sup>(2,8,11)</sup> the knee was the most common site of injury. Injuries to the calf, lower back, posterior thigh and ankle injuries were also present in these studies. Bredeweg et al <sup>(1)</sup> found the knee most common site of injury (39%). Taunton et al <sup>(2)</sup> found similar results with both male (36%) and female (32%) participants, reporting the knee as the most common site <sup>(2)</sup>. In contrast, a study on collegiate cross-country runners found medial lower leg pain was the most common presentation <sup>(42)</sup>. The high forces on the knee has been studied during the running gait and this might cause the increased load on the joint <sup>(19)</sup>. A limitation in this present study was that the location (anterior, medial, posterior or lateral) of the knee injury was not specified. Futures studies need to identify the exact location and structures involved.

### **3.9.3.3 Pain associated with running-related injuries**

Pain scores were relatively low for acute injuries in this study. A possible explanation for these low pain scores might be due to the low training load of the participants, as well as the number of rest days included during the eight-week study period. The interpretation of pain also needs to be taken into consideration. Perhaps participants did not actually have an injury, but perhaps the pain that they experienced was related to muscle damage associated with intense or unaccustomed exercise. Delayed onset muscle soreness peaks at 24 to 48 hours after exercise <sup>(4,29)</sup>, which fits into the rest period described by participants in this study. Pain is also not an accurate measurement of tissue damage and thus the severity of the injury cannot be determined. More accurate measurements need to be considered in future studies.

Further, in this study, the management strategy of choice in this study was self-medication. While we did not investigate this further (in terms of type of medication and pattern of use), this is potentially a concern. Over-the-counter (OTC) medication could hold potential harm for novice runners. In a recent survey, the uses of non-steroidal anti-inflammatory drug (NSAIDs) were very high amongst athletes <sup>(95)</sup>. The adverse effects of regular use of these drugs include dyspepsia, nausea, ulcers and bleeding. Even after one month of regular use the relative risk increases for bleeding in the upper gastrointestinal tract <sup>(95)</sup>.

In our study, only two participants sought medical help after sustaining a RRI. Compared to other studies, experienced runners tend to seek more medical attention <sup>(11)</sup>. The low score of pain associated with the injury or the lack of knowledge of when to seek medical help could have resulted in these findings in our study. These findings indicate that novice runners need to be educated on the use of OTC medication, appropriate dosages and timing of use of medication, and when it is appropriate to stop running and seek from a physiotherapist or another member of the multi-disciplinary team.

#### **3.9.4 Factors predicting running-related injuries**

This study was unable to identify any training or biomechanical factors that were predictive of a RRI. In this study, the only predictive factor that was associated with an increased risk of RRI was a previous history of injury. This finding correlates with the literature that previous history of injury is a very high predictor for RRI <sup>(8,10,18)</sup>. Nielsen et al <sup>(13)</sup> found that runners with a previous non-related running injury sustained 11.1% more injuries compared to healthy runners. This suggests that proper rehabilitation of an injury is necessary to avoid re-injury. The difficulty lies in how to identify when an injury is fully rehabilitated. In the absence of pain, many runners might think that the injury has healed but physiologically more recovery might still be necessary <sup>(13)</sup>. These findings suggest that runners require education regarding the importance of compliance with rehabilitation, as well as clear guidelines regarding when it is safe to return to running training and competition.

No other descriptive characteristics were found as a predictive factor for RRI. In this study both the injured and uninjured groups had a relatively high BMI. Other studies have shown similar results with a higher BMI as even being a protective factor against RRI<sup>(2,9,13)</sup>. This might be due to runners with a higher BMI tending to train less and not as vigorously. In this study, the low training volumes might contribute to the lack of association between BMI and injury risk.

Participation in other sports have also been implicated as a risk factor for RRI<sup>(21)</sup>, but this was not observed in our study. Buist et al<sup>(21)</sup> found participation in sport without axial loading increased the risk for RRI in male novice runners. In comparison, this study included both male and female athletes, had a much smaller study size, and 50% of participants took part in running training only, which may contribute to the lack of association between participation in other sports and RRI.

There were no associations between any of the musculoskeletal tests and RRI in this study. These findings are supported by Lun et al<sup>(44)</sup> who found no relationship between static lower limb alignment and RRI. Patellofemoral joint pain (PFJP) syndrome has been implicated with an increased Q-angle<sup>(57,58)</sup>, but in this study an increased Q-angle was not associated with a risk for RRI. In this study, the relatively small sample size, and the static assessment of Q-angle might have contributed to our findings.

The navicular drop test was also not a predictive factor for RRI in this study. This is in contrast to a study by Moen et al<sup>(96)</sup>, where a positive navicular drop test to be a risk factor for developing medial tibial stress syndrome (MTSS). However, the assessment of navicular drop was done retrospectively<sup>(96)</sup>, which may account for the differences between this study and the current study findings. Buist et al<sup>(21)</sup> observed that the navicular drop test was only predictive for RRI in female runners. However, this study differs from the current study as almost half of the female participants (48%) had some previous running experience, and 51% of female participants had a history of previous injury<sup>(21)</sup>. These differences in participants' characteristics could account for the contrasting results of Buist et al<sup>(21)</sup> and the current study.

In this study, there was also no association between hamstring flexibility and RRI. Previous studies have shown that decrease hamstring flexibility may be associated with increased injury risk, and that decrease hamstring flexibility may be correlated with high training mileage<sup>(14,71)</sup>. It is possible that the low training loads of participants in this study were insufficient to place the hamstring muscle group at risk of injury.

Further, in this study balance was also not found to be a predictive factor of RRI. In previous studies, decreased balance has been shown to increase the risk of injury in athletes <sup>(67)</sup>, but none of these studies were on runners. The specificity and sensitivity of the SEBT in runners also needs to be researched in future studies. As the movements of the SEBT are not similar to the running style, other dynamic balance tests might be more accurate for assessing deficits in balance in novice and experienced runners.

### **3.9.5 Clinical implications**

There are a number of important clinical recommendations that have been highlighted by the findings of this study.

Due to the high incidence of RRI's in novice runners (evidenced in this study and previous research), clinicians need to ensure that they conduct a thorough assessment to identify any history that could increase the individual's risk of injury. While the risk of injury is high, novice runners also need to be educated regarding injury mechanisms and presentations, to distinguish between an injury and pain/DOMS that may be associated with intense or unaccustomed exercise; and when it is safe to continue exercising in the presence of pain or discomfort.

As reported in other studies on RRI <sup>(8,16,47)</sup>, the knee was the most common site of injury in this study. Although the type of injury was not specified in this study, the high prevalence of knee injuries across different studies indicates that clinicians should be aware of the increased susceptibility of runners to knee injuries. Future research could include the effects of a pre-participation knee strengthening programme on injury risk in both novice and experienced runners.

In addition, in this study, the majority of participants managed their injuries through self-medication. Even though the type of self-medication was not specified, the selection of self-medication as the preferred management for musculoskeletal injuries is of concern to clinicians.

Clinicians need to understand runners' goals when they start exercising, so that we can ensure that the running training programme is appropriate to achieve those goals. Physiotherapists must also have good knowledge of the principles of exercise

prescription to ensure that appropriate modifications and recommendations can be made to training programmes.

Novice runners need to be educated about the risks and benefits of over-the-counter medication, appropriate dosages and timing of use of medication, and when it is appropriate to seek from a physiotherapist or another member of the multi-disciplinary team.

### **3.9.6 Limitations of this study and recommendations for future research**

Limitations of this study include the short study period. It is recognised that determining injury incidence over a longer running training period would be advantageous, and would allow the calculation of injury incidence per 1000 training hours, as is done in many other sports injury incidence studies <sup>(13,48)</sup>. However, the duration of this study was unfortunately limited due to the requirements of the MPhil degree.

The sample size of this study might also have influenced some results. Sample size for this study was calculated according to training frequency. It is recognised that there is a possible of Type 2 errors in post-hoc analysis. A larger sample size is needed to confirm findings related to training distance and duration.

The method of documenting injuries in this study was limited, and we recognise that important information regarding a detailed injury history, as well as more detailed description of the injuries sustained during the study period were lacking. A clearer differentiation between pain associated with injury, and the pain and discomfort associated with unaccustomed exercise was also needed to ensure accurate documentation of a RRI. Recommendations for future studies also include a more thorough pain and injury assessment, as well as a more detailed description of previous injury history.

The pain scores associated with the injuries in this study were relatively low. The interpretation of pain needs to be clarified in future research studies to ensure that participants understand the difference between pain related to DOMS and an actual musculoskeletal injury.

In addition, the reasons for runners starting training programmes in their 30s needs to be researched. Advice regarding maintaining a healthy lifestyle and training habits from an earlier age may need to be addressed.

Finally, it would be useful to consider evaluating the incidence of injuries in novice runners who are following a standardised training programme that meets current evidence-based guidelines. This would ensure that novice runners are experiencing sufficient training loads to allow adaptations associated with endurance exercise and related health benefits; and to allow the careful evaluation of injury risk at these training loads.

## Chapter 4: Summary and conclusion

Running is popular sport in South Africa and worldwide <sup>(21)</sup>. However, the rise in participation in running has been associated with an increase in running-related injuries (RRI) <sup>(8,9,15)</sup>. There are numerous intrinsic and extrinsic risk factors associated with RRI, and the aetiology of RRI may be multifactorial and diverse <sup>(8,10,15–17)</sup>. However, few studies have prospectively examined the risk factors for injuries in novice runners <sup>(8,16,17)</sup>. Injury often results in time off training, and may cause individuals to drop out of specific training programmes <sup>(19)</sup>. As many individuals start running to achieve the health benefits associated with regular cardiovascular exercise <sup>(3,5,6,28,31)</sup>, it is important to minimise any prolonged time off training, and to facilitate regular and safe participation in the sport <sup>(19)</sup>.

Therefore, the overall aim of this study was to prospectively determine the risk factors for lower limb musculoskeletal injuries in novice runners. Based on the evidence provided in this dissertation, the study objectives as described in Section 1.2 (page 2) may be answered as follows:

- *To describe the demographic and training characteristics of novice runners.*

The average BMI was high in both groups, with participants in the injured group classified as overweight, and participants in the uninjured group classified in the upper limit of normal weight. Further, 10% of participants reported a history of chronic diseases of lifestyle, despite the mean age of both groups being under 35 years of age. Weekly training distance and duration, and session RPE were consistently higher in the injured group, compared to the uninjured group, but these differences were not significant. However, participants in the injured and uninjured groups only trained on average  $25 \pm 5$  and  $22 \pm 5$  days over the eight-week study period respectively. The average session training distance and duration for participants in the injured and uninjured groups were  $5.2 \pm 1.9$ km and  $4.4 \pm 1.1$ km; and  $33 \pm 10$  min and  $28 \pm 6$  min respectively. In addition, 50% of participants took part in running training only. Those participants who did take part in other sports generally engaged in these activities twice a week. The demographic profile of participants in this study emphasises the growing concern regarding overweight and obesity and the burden of non-communicable diseases in the South African population.

Novice runners may also benefit from a structured training programme, with careful progression of training loads, to both minimise the risk of injury and to ensure the health benefits of regular cardiovascular exercise are achieved.

- *To establish the incidence of self-reported running-related injuries in novice runners.*

Fifteen participants (37%) sustained a RRI during the study period, with a total of 20 RRIs being reported during the eight-week training period. Injury incidence was highest during weeks two and six of the training period. The knee was the most common site of injury. Participants reported mild to moderate pain scores associated with injury, and rested from running training for an average of three days post-injury. The majority of participants managed their injuries with self-medication. The injury incidence in this study is comparable to previous studies. Of concern is the relatively high injury incidence associated with relatively low training loads during a comparatively short study period. These findings suggest that novice runners may be vulnerable to injury, and highlight the importance of effective pre-participation screening and education of runners.

- *To determine if specific intrinsic factors, namely age, gender, body mass index, quadriceps angle, foot alignment, hamstring flexibility, balance, muscle power and a history of previous injury are risk factors for lower limb musculoskeletal injuries in novice runners.*

The only predictive factor that was associated with an increased risk of lower limb musculoskeletal injury was a previous history of injury. In this study, runners with an injury history were approximately 17 times more likely to sustain a lower limb musculoskeletal injury during the eight-week study period, compared to runners with no injury history. However, the large confidence intervals suggest that this finding should be interpreted with caution, and that further studies with larger sample sizes are needed to confirm this finding. This study was unable to identify any biomechanical factors that were predictive of lower limb musculoskeletal injuries.

- *To determine if specific extrinsic factors, namely training frequency, session duration, and intensity are risk factors for developing lower limb musculoskeletal injuries in novice runners.*

This study was unable to identify any specific extrinsic risk factors for lower limb musculoskeletal injuries in novice runners.

Weekly training distance and duration, and session RPE were consistently higher in the injured group, compared to the uninjured group, but these differences were not significant. Overall cumulative training days, and individual training session distance and duration were low in both groups. Participants also exercised at low to moderate intensities.

Although it is possible that relatively low training loads might limit the risk of RRI, it is questionable whether the training loads were sufficient to achieve endurance training adaptations or health benefits associated with regular cardiovascular exercise over the eight-week study period.

In conclusion, the findings of this study indicate that the incidence of lower limb musculoskeletal injuries in novice runners is relatively high. Careful pre-participation screening is needed to identify risk factors for injury in this potentially vulnerable group. Education is essential to ensure that runners understand the principles of exercise progression and the minimum training requirements to achieve the health benefits of regular endurance exercise, and to minimise the risk of injury.

## Chapter 5: References

1. Bredeweg S, Zijlstra S, Bessem B, Buist I. The effectiveness of a preconditioning programme on preventing running-related injuries in novice runners: a randomised controlled trial. *Br J Sport ...* [Internet]. 2012 [cited 2015 May 13];0:1–7. Available from: <http://bjsm.bmj.com/content/46/12/865.short>
2. Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A prospective study of running injuries: the Vancouver Sun Run “In Training” clinics. *Br J Sports Med.* 2003 Jun;37(3):239–44.
3. Thompson WR, Gordon NF, Pescatello LS. ACSM’s guidelines for exercise testing and prescription. Eight edit. Lippincott, Williams @ Wilkens; 2009.
4. Brukner P, Khan K. *Clinical Sports Medicine.* 4th ed. North Ryde NSW: McGraw-Hill Australia Pty Ltd; 2007.
5. Brooks GA, Fahey TD BK. *Exercise Physiology. Human bioenergetics and its applications.* Fourth Edi. New York: McGraw Hill Companies; 2005.
6. Hansen P, English M, Willick SE. Does running cause osteoarthritis in the hip or knee ? *Phys Med Rehabil J. Elsevier Inc.;* 2012;4(5):S117–S121.
7. Boudreau AL, Giorgi B. The experience of self-discovery and mental change in female novice athletes in connection to marathon running. *J Phenomenol Psychol.* 2010;41:234–67.
8. Fredericson M, Misra A. Epidemiology and aetiology of marathon running injuries. *Sport Med.* 2007;37:437–9.
9. Van Gent R, Siem D, Van Middelkoop M, Van Os A, Koes B. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med.* 2007;41:469–81.
10. Van Mechelen W. Running injuries. A Review of the epidemiological literature. *Sport Med.* 1992;14(5):320–35.
11. Van Middelkoop M, Kolkman J, Van Ochten J, Bierma-Zeinstra S, Koes B. Course and predicting factors of lower-extremity injuries after running a marathon. *Clin J Sport Med.* 2007;17(1):25–30.
12. Buist I, Bredeweg S. Higher risk of injury in overweight novice runners. *Br J Sports Med.* 2011;(45):310–84.
13. Nielsen RO, Buist I, Parner ET, Nohr EA, Sørensen H, Lind M. Predictors of running-related injuries among 930 novice runners. A 1-year prospective follow-up study. *Orthop J Sport Med.* 2013;1(1):1–7.
14. Sole G, Milosavljevic S. Running-related hamstring injuries: a neuromuscular approach. *Phys Ther Rev.* 2008;13(2):102–10.

15. Hreljac A. Impact and overuse injuries in runners. *Int J Sports Med.* 2006;7(2):98–108.
16. Wen DY. Risk factors for overuse injuries in runners. *Curr Sports Med Rep.* 2007;6:307–13.
17. Buist I, Bredeweg SW, Bessem B, Mechelen W Van, Lemmink KAPM, Diercks RL. Incidence and risk factors of running-related injuries during preparation for a 4-mile recreational running event. *Br J Sports Med.* 2010;44:598–604.
18. Buist I, Bredeweg SW, Lemmink KAPM, Pepping J, Zwerver J, Mechelen W Van, et al. No Effect of a Graded Training Program on the Number of Running-Related Injuries A Randomized Controlled Trial. *Am J Sport Med.* 2008;36(2):33–9.
19. Chorley J, Cianca J, Divine J, Hew T. Baseline injury risk factors for runners starting a marathon training program. *Clin J Sport Med.* 2002;12(1):18–23.
20. Bredeweg SW, Zijlstra S, Bessem B, Buist I. Effectiveness of a preconditioning program on preventing running related injuries in novice runners. *Br J Sports Med.* 2012;0:1–7.
21. Buist I, Bredeweg SW, Lemmink KAPM, Mechelen W Van, Diercks RL. Predictors of running-related injuries in novice runners enrolled in a systematic training program: a prospective cohort study. *Br J Sports Med.* 2010;38:273–80.
22. Walter S, Hart L, McIntosh J et al. The Ontario cohort study of running-related injuries. *Arch Intern Med.* 1989;149:2561–4.
23. Schwellnus M, Stubbs G. Does running shoe prescription alter the risk of developing a running injury? *Int Sport Med Journal.* 2006;7:138–53.
24. Junior LCH, Carvalho ACA, Lopes AD. A description of training characteristics and its association with previous musculoskeletal injuries in recreational runners : a cross-sectional study. 2012;16(1):46–53.
25. Wilk BBR, Nau S, Valero B. Physical therapy management of running injuries using an evidenced based functional approach. *AMAA.* 2009;(Winter Journal).
26. New York City Marathon [Internet]. [cited 2014 Apr 22]. Available from: [www.wikipedia.org/wiki/New\\_York\\_City\\_Marathon](http://www.wikipedia.org/wiki/New_York_City_Marathon)
27. Boulter J, Manser T. Comrades marathon: Event statistics. 2012 [Internet]. 2012 [cited 2014 Jul 1]. Available from: <http://www.comrades.com/History/Statistics.aspx>.
28. King N.A., Hopkins M., Caudell P., Stubbs R.J. Beneficial effects of exercise: shifting the focus from body weight to other markers of health. *Br J Sports Med.* 2009;43:924–7.
29. Lambert M, Borresen J. A theoretical basis of monitoring fatigue: a practical approach for coaches. *Int J Sport Sci Coach.* 2006;1:371–88.

30. Kolt G, Snyder-Mackler L. Physical therapies in sport and exercise. 2nd ed. Philadelphia: Elsevier Churchill Livingstone; 2007.
31. Schreuder THA, Maessen MFH, Tack CJ, Thijssen DHJ, Hopman MTE. Life-long physical activity restores metabolic and cardiovascular function in type 2 diabetes. *Eur J Appl Physiol*. 2014 Mar;114(3):619–27.
32. Harber M, Crane J, Dickinson J, Jemiolo B, Raue U, Trappe T, et al. Protein synthesis and the expression of growth-related genes are altered by running in human vastus lateralis and soleus muscles. *Am J Physiol Regul Integr Comp Physiol*. 2009;47306:708–14.
33. Paavolainen L, Häkkinen K, Hämmäläinen I, Nummela A, Keefe ZB, Helgerud J, et al. Explosive-strength training improves 5-km running time by improving running economy and muscle power muscle bed. *J Appl Physiol*. 1999;86:1527–33.
34. Szabo A, Abrahám J. The psychological benefits of recreational running: a field study. *Psychol Health Med*. 2013 Jan;18(3):251–61.
35. Tsatalas T, Giakas G, Syropoulos G, Sideris V, Lazaridis S, Kotzamanidis C, et al. The effects of eccentric exercise-induced muscle damage on running kinematics at different speeds. *J Sports Sci*. 2013 Jan;31(3):288–98.
36. Marcora SM, Bosio A. Effect of exercise-induced muscle damage on endurance running performance in humans. *Scand J Med Sci Sports*. 2007 Dec;17(6):662–71.
37. Murase S, Terazawa E, Queme F, Ota H, Matsuda T, Hirate K, et al. Bradykinin and nerve growth factor play pivotal roles in muscular mechanical hyperalgesia after exercise (delayed-onset muscle soreness). *J Neurosci*. 2010 Mar 10;30(10):3752–61.
38. Kentta G HP. Overtraining and Recovery. A conceptual model. *Sport Med*. 1998;26:1 –16.
39. Denadai B, Greco C, Tufik S, de Mello M. Effects of high intensity running to fatigue on isokinetic muscular strength in endurance athletes. *Isokinet Exerc Sci*. 2007;12(15):281–5.
40. McCullough PA, Chinnaiyan KM, Gallagher MJ, Colar JM, Geddes T, Gold JM, et al. Changes in renal markers and acute kidney injury after marathon running. *Nephrology (Carlton)*. 2011 Feb;16(2):194–9.
41. Bovens A, Janssen G, Vermeer H, Hoeberrigs J, Janssen M, Verstappen F. Occurrence of running injuries in adults following a supervised training program. *Int J Sport Med*. 1989;10(3):186–90.
42. Reinking MF, Austin TM HA. Exercise-Related Leg Pain in collegiate cross-country athletes: extrinsic and intrinsic risk factors. *J Orthopaedic Sport Phys Ther*. 2007;37:670–81.

43. Rauh MJ, Koepsell TT, Rivara FP, Rice MPHSG, Margherita MPH AJ. Quadriceps angle and risk of injury among high school cross-country runners. *J Orthopaedic Sport Phys Ther.* 2007;37(12):725–33.
44. Lun V., Meeuwisse W.H., Stergiou P. SD. Relation between running injuries and static lower limb alignment in recreational runners. *Br J Sports Med.* 2004;38(VI):576–80.
45. Obremskey WT, Pappas N, Attallah-Wasif E, Tornetta P, Bhandari M. Level of evidence in orthopaedic journals. *J bone Jt surgery [Internet].* 2005 Dec;87(12):2632–8. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/16322612>
46. Daoud A, Geissler G, Wang F, Saretsky J, Daoud Y, Lieberman D. Foot strike and injury rates in endurance. *Am Coll Sport Med.* 2012;1325–34.
47. Nielsen RO, Buist I, Sørensen H, Lind M. Training errors and running-related injuries: a systematic review. *Int J Sports Phys Ther.* 2012;7(1):58–75.
48. Buist I, Bredeweg SW, Van Mechelen W, Lemmink KAPM, Pepping J, Diercks RL. No effect of a graded training program on the number of running-related injuries a randomized controlled trial. *Am J Sport Med.* 2008;36(2):33–9.
49. Taunton J, Ryan M, Clement D, McKenzie D, Lloyd-Smith D, BD Z. A retrospective case controlled analysis of 2002 running injuries. *Br J Sports Med.* 2002;36:95–101.
50. Knapik JJ, Trone DW, Swedler DI, Villasenor A, Bullock SH, Schmied E, et al. Injury reduction effectiveness of assigning running shoes based on plantar shape in military recruits. *Am J Sports Med.* 2010;38(9):1759–67.
51. Mehl AJ, Nelson NG, McKenzie LB. Running-related injuries in school-age children and adolescents treated in emergency departments from 1994 through 2007. *Clin Pediatr (Phila).* 2011 Feb;50(2):126–32.
52. Satterthwaite P, Norton R, Robinson E, Larmer P. Risk factors for injuries and other health problems sustained in a marathon. *Br J Sports Med.* 1999;33:22–6.
53. Milner CE, Ferber R, Pollard CD, Hamill J, Davis IS. Biomechanical factors associated with tibial stress fracture in female runners. *Am Coll Sport Med.* 2006;(5):323–8.
54. Rauh MJ, Macera CA, Trone DW, Reis JP, Shaffer RA. Selected static anatomic measures predict overuse injuries in female recruits. *J Orthopaedic Sport Phys Ther.* 2010;175(May):329–36.
55. Nguyen A, Shultz S. Sex differences in clinical measures of lower extremity alignment. *J Orthopaedic Sport Phys Ther.* 2007;37(7):389–98.
56. Heiderscheit B, Hamill J, Caldwell G. Influence of Q-angle on lower-extremity running kinematics. *J Orthopaedic Sport Phys Ther.* 2000;30(5):271–8.

57. Messier S, Davis S, Curl W et al. Etiologic factors associated with patellofemoral pain in runners. *Med Sci Sports Exerc.* 1991;23:1008–15.
58. Moss RI, DeVita P, Dawson M. A biomechanical analysis of patellofemoral stress syndrome. *J Athl Train.* 1992;27:64–9.
59. Powers C. The influence of altered lower-extremity kinematics on patellofemoral joint dysfunction: a theoretical perspective. *J Orthopaedic Sport Phys Ther.* 2003;3(11):639–46.
60. Nicola TL, Jewison DJ. The anatomy and biomechanics of running. *Clin J Sport Med.* Elsevier; 2012;31(2):187–201.
61. Grau S, Maiwald C, Krauss I, Axmann D, Janssen P, Horstmann T. What are causes and treatment strategies for patellar-tendinopathy in female runners ? 2008;41:2042–6.
62. Cheung R, Ng G. A systematic review of running shoes and lower leg biomechanics: a possible link with patellofemoral pain syndrome? *Int J Sport Med.* 2007;8:107–16.
63. Mohamad, Shariff A Hamid Mohamed, Razif Mohamed Ali Ashril Y. Interrater and intrarater reliability of the active knee extension ( AKE ) test among healthy adults. *J Phys Ther Sci.* 2013;25(8):957–61.
64. Watsford M, Murphy A, McLachlan K, Bryant A, Cameron M, Crossley K, et al. A prospective study of the relationship between lower body stiffness and hamstring injury in professional Australian rules footballers. *Am J Sport Med.* 2010;38(10):2058–64.
65. Hreljac A, Marshall R, Hume P. Evaluation of lower extremity overuse injury potential in runners. *Med Sci Sports Exerc.* 2000;32(9):1635–41.
66. Bentley D, Zhou S, Davie A. The effect of endurance exercise on muscle force generating capacity of the lower limbs. *J Sci Med Sport.* 1998;9(1):179–88.
67. Hrysomallis C. Relationship between balance ability , training and sports injury risk. 2007;37(6):547–56.
68. Willems T, Witvrouw E, Delbaere K. Intrinsic risk case control study of a prevention training program in female factors for inversion ankle sprains in females: a prospective team handball players: the German experience. *Scand J Med Sci Sport.* 2005;15(5):336–45.
69. Endo Y, Sakamoto M. Relationship between lower extremity tightness and star excursion balance test performance in junior high school baseball players. *J Phys Ther Sci.* 2014;26(5):8–10.
70. Macera C, Pate R, Powell K et al. Predicting lower extremity injuries among habitual runners. *Arch Intern Med.* 1989;149:2565–8.

71. Silder A, Thelen DG, Heiderscheit BC. Effects of prior hamstring strain injury on strength, flexibility, and running mechanics. *Clin Biomech (Bristol, Avon)*. Elsevier Ltd; 2010 Aug;25(7):681–6.
72. Rudzki SL. Injuries in Australian army recruits. Part III: the accuracy of a pretraining screen in predicting ultimate injury outcome. *Military Med*. 1997;162:481–3.
73. Yeung E.W & Yeung S.S. A systematic review of interventions to prevent lower limb soft tissue running injuries. *Br J Sports Med*. 2001;35:383–9.
74. Gabbett T, Ullah S. Soft tissue injury in elite team sport. *J Strength Cond Res*. 2012;26(4).
75. Knapik JJ, Swedler D, Grier T et al. Injury reduction effectiveness of selecting running shoes based on plantar shape. *J Strength Cond Res*. 2009;23:685–97.
76. Diebal AR, Gregory R, Alitz C, Gerber JP, Diebal MAJAR, Alitz COLC. Forefoot Running Improves Pain. *Am J Sport Med*. 2012;40.
77. Wang L, Hong Y, Li J, Zhou J. Research in Sports Medicine : An Comparison of Plantar Loads During Running on Different Overground Surfaces. *Res Sport Med*. 2012;20(August):75–85.
78. Tessutti V, Ribeiro AP, Trombini-souza F, Sacco ICN. Attenuation of foot pressure during running on four different surfaces : asphalt , concrete , rubber , and natural grass. *J Sport Sci*. 2012;(October 2012):37–41.
79. Milgrom C, Finestone A, Segev S, Olin C, Arndt T, Ekenman I. Are overground or treadmill runners more likely to sustain tibial stress fracture? *Br J Sports Med*. 2003;37:160–3.
80. Burnstein B, Steele R, Shrier I. Reliability of fitness tests using methods and time periods common in sport and occupational management. *J Athl Train*. 2011;46(5):505–13.
81. Smith TO, Hunt NJ, Donell ST. The reliability and validity of the Q-angle : a systematic review. *Knee Surg Sport Traumatol*. 2008;16:1068–79.
82. Mueller M, Host J, Norton B. Navicular drop as a composite measure of excessive pronation. *J Am Pod Med Assoc*. 1993;(83):198–202.
83. Nguyen A, Shultz S. Sex differences in clinical measurement of Lower Extremity Alignment. *J Orthopaedic Sport Phys Ther*. 2007;37(7):389–98.
84. Cameron DM, Bohannon EW. Relationship between active knee extension and active straight leg raise test measurements. *J Orthopaedic Sport Phys Ther*. 1993;17(5).
85. Hopkins W, Schabort E, Hawley J. Reliability of power in physical performance tests. *J Sports Med*. 2001;31(3):211–34.

86. Demura S, Yamada T. Proposal for a practical star excursion balance test using three trials with four directions. *Sport Sci Heal*. 2010;1:1–8.
87. Kinzey S, Armstrong CW. The Reliability of the star-excursion test in assessing dynamic balance. *J Orthopaedic Sport Phys Ther*. 1998;27(5):356–60.
88. Gomez-Pirez P, Jimenez-Reyes P, Ruiz-Ruiz C. Relation between total body load and session rating of perceived exertion in professional soccer players. *J Strength Cond Res Cond Res*. 2011;25(8):2100–3.
89. Borges T, Bullock N, Duff C, Coutts A. Methods for quantifying training in sprint kayak. *J Strength Cond Res*. 2014;28(2):474–82.
90. Lupo C, Capranica L, Tessitore A. The validity of session-RPE method for quantifying training load in water polo. *Int J Sports Physiol Perform*. 2014;9(4):656–60.
91. Reurink G, Goudswaard GJ, Oomen HG, Moen MH, Tol JL, Verhaar J a N, et al. Reliability of the active and passive knee extension test in acute hamstring injuries. *Am J Sports Med*. 2013 Aug;41(8):1757–61.
92. Bruce B, Fries JF, Lubeck DP. Aerobic exercise and its impact on musculoskeletal pain in older adults: a 14 year prospective, longitudinal study. *Arthritis Res Ther*. 2005 Jan;7(6):1263–70.
93. Oni T, McGrath N, Belue R, Roderick P, Stephen C, Eduau S, et al. Chronic diseases and multi-morbidity - a conceptual modification to the WHO ICCD model for countries in health transition. *Biomed Cent Public Heal*. 2014;14:575.
94. Foster C. Monitoring training in athletes with reference to overtraining syndrome. *Med Sci Sport Exerc*. 1998 Jul;30(7):1164–8.
95. Ziltener J-L, Leal S, Fournier P-E. Non-steroidal anti-inflammatory drugs for athletes: an update. *Ann Phys Rehabil Med*. Elsevier Masson SAS; 2010 May;53(4):278–82, 282–8.
96. Moen MH, Bongers T, Bakker EW, Zimmermann WO, Weir A, Tol JL, et al. Risk factors and prognostic indicators for medial tibial stress syndrome. *Scand J Med Sci Sports*. 2012 Feb;22(1):34–9.

## Appendix I - Recruitment advertisement



UCT/MRC Research Unit for Exercise Science and Sports Medicine  
Department of Human Biology  
Division of Physiotherapy, Department of Health & Rehabilitation Sciences  
Faculty of Health Sciences  
University of Cape Town, South Africa



### NOVICE RUNNERS NEEDED FOR UCT RESEARCH

For study investigating the risk factors for lower limb musculoskeletal injuries in novice runners

**Study outline**

I am a Masters student at UCT, investigating the risk factors for the development of lower limb musculoskeletal injuries in novice runners. The study aims to provide information regarding preventative measures for novice runners when starting a training program to avoid running injuries.

The study requires you to complete a medical and physical activity questionnaire as well as musculoskeletal screening tests before the start of the training program. You will be requested to keep a detailed training and running related injury logbook during an 8 week training program.

**Those interested in participating should be..**

- starting a running program with Run/Walk for Life club
- between the ages of 21 and 45 years
- have no injuries in the last 6 months
- have not been running on a regular basis for the last 12 months

**Benefits of participating in the study include**

- Individual anthropometric measurements (Height, weight, BMI) as well as musculoskeletal assessment tests
- Feedback regarding the results of the study
- Information booklet on running related injuries and prevention thereof will be handed out to participants

**DEADLINE FOR APPLICATIONS: 31 January 2012**

**If you are interested in taking part in the study and would like additional information, please contact:**



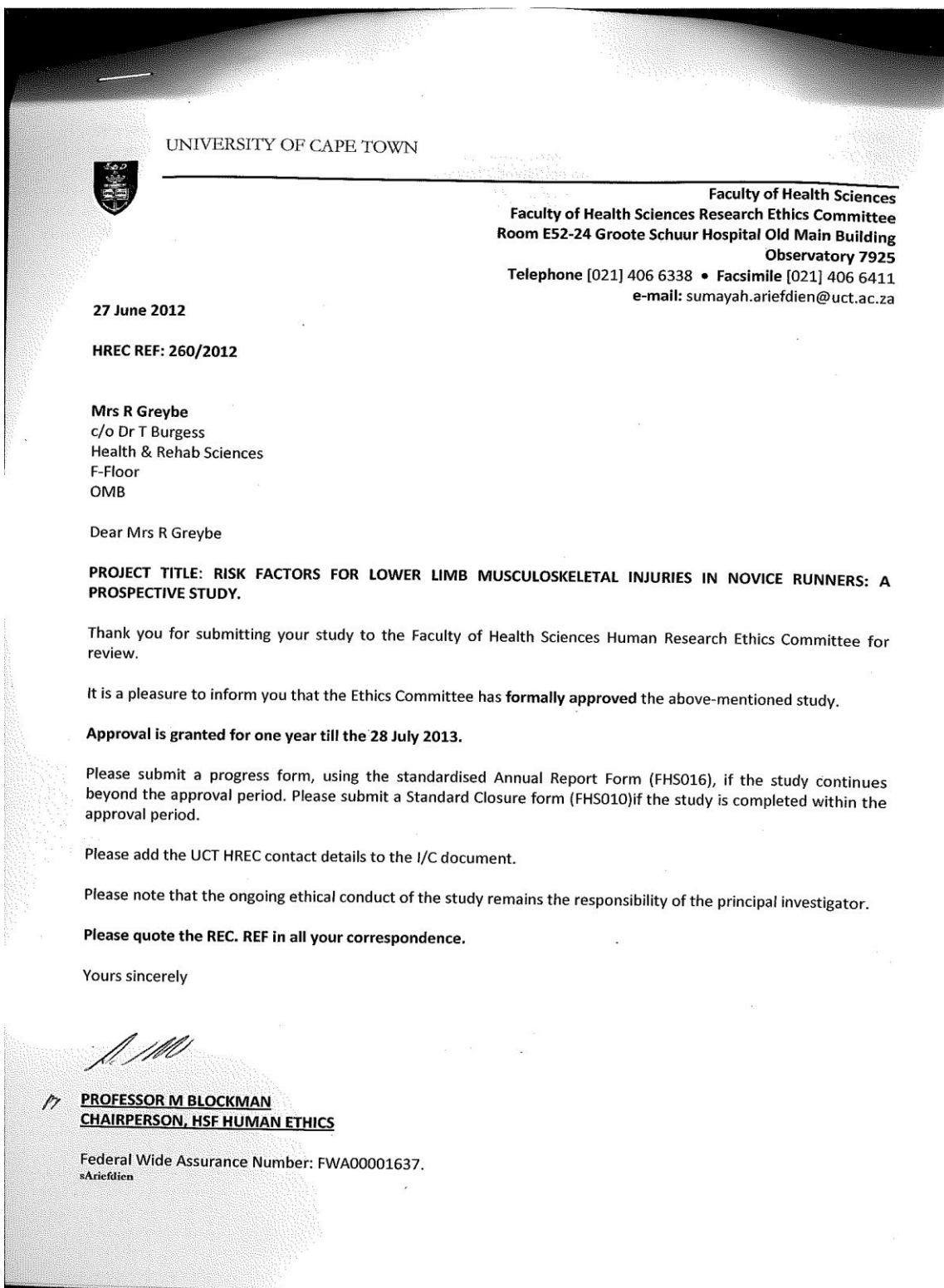
**SPORTS  
SCIENCE**  
SOUTH AFRICA



**essm**  
EXERCISE SCIENCE AND SPORTS MEDICINE

Rykie Greybe  
Cell: 0731804427

## Appendix II - Ethics Approval



## Appendix III - PAR-Q questionnaire

### Modified Physical Activity Readiness Questionnaire (PAR-Q)

<b>Name</b>			<b>Date</b>
<b>DOB</b>	<b>Age</b>	<b>Home Phone</b>	<b>Work Phone</b>

Regular exercise is associated with many health benefits, yet any change in activity may increase the risk of injury. Completion of this questionnaire is a first step when planning to increase the amount of physical activity in your life. Please read each question carefully and answer every question honestly:

<b>Yes</b>	<b>No</b>	1) Has a physician ever said you have a heart condition and you should only do physical activity recommended by a physician?
<b>Yes</b>	<b>No</b>	2) When you do physical activity, do you feel pain in your chest?
<b>Yes</b>	<b>No</b>	3) When you were not doing physical activity, have you had chest pain in the past month?
<b>Yes</b>	<b>No</b>	4) Do you ever lose consciousness or do you lose your balance because of dizziness?
<b>Yes</b>	<b>No</b>	5) Do you have a joint or bone problem that may be made worse by a change in your physical activity?
<b>Yes</b>	<b>No</b>	6) Is a physician currently prescribing medications for your blood pressure or heart condition?
<b>Yes</b>	<b>No</b>	7) Are you pregnant?
<b>Yes</b>	<b>No</b>	8) Do you have insulin dependent diabetes?
<b>Yes</b>	<b>No</b>	9) Are you 69 years of age or older?
<b>Yes</b>	<b>No</b>	10) Do you know of any other reason you should not exercise or increase your physical activity?

If you answered yes to any of the above questions, talk with your doctor BEFORE you become more physically active. Tell your doctor of your intent to exercise and to which questions you answered yes. If you answered no to all questions, you can be reasonably positive that you can safely increase your physical activity gradually. If your health changes so you then answer yes to any of the above questions, seek guidance from a physician.

**Participant Signature**

**Date**

## Appendix IV - Informed consent form

UNIVERSITY OF CAPE TOWN

DEPARTMENT OF HEALTH AND REHABILITATION SCIENCES

DIVISION OF PHYSIOTHERAPY

Consent Form

A study to determine the risk factors for developing lower limb musculoskeletal injuries in novice runners

Dear Participant

This informed consent form is for novice runners, starting a running programme. I am inviting you to participate in the research titled "Risk factors for lower limb musculoskeletal injuries in novice runners: A prospective study". Information obtained within the study will be used for my MPhil Sports Physiotherapy research thesis. This study has been given ethical approval by the Human Research Ethics Committee, Faculty of Health Sciences, University of Cape Town (HREC REF 260/2012).

Most runners will experience some form of injury during their running career. This can be due to various intrinsic or extrinsic risk factors. The aim of this study is to identify possible risk factors to lower limb injuries in novice runners starting a running training programme. By identifying these risk factors, athletes, health professionals and trainers can possibly prevent the occurrence of running injuries and aid in developing screening tests for novice runners.

Participation in this study is completely voluntary. If you decide not to participate there will be no negative consequences. Please be aware that if you do decide to participate, you may withdraw from the study at any time. Participation in this study will not interfere with your running training and you may continue with other physical activities and sports. This study will be supervised by Dr Theresa Burgess and Professor Mike Lambert from the University of Cape Town. Please take time to read this form thoroughly before signing.

The research would involve your participation in filling in a questionnaire regarding personal detail, medical and injury history as well as current physical activity level when you start the running programme. Before the start of your training programme you will then be required to attend one session of testing at the club. You will be familiarised with all testing procedures that will be used during the study. The testing procedure will be explained and any questions will be addressed. An electronic logbook will be kept daily during an eight week training intervention.

Your weight and height will be measured to calculate your body mass index (BMI). You will then be asked to undergo a session of screening tests before the start of your training programme. This would involve the following tests:

The Q-angle:

A measurement line from the anterior iliac spine to the centre of the patella and from the centre of the patella to the centre of the tibial tubercle will be drawn. (From the front of the hip bone to the patella and from the patella to the centre of the lower leg). The line will be measured with a tape measure and will be drawn with a pen. Both legs will be tested. Three measurements will be taken.

### The navicular drop test

This will test the amount of pronation in the subtalar (ankle) joint. Measurements from the navicular tuberosity (foot bone) to the floor will be taken in sitting and standing and the difference will be taken as the amount of pronation. A pencil mark will be made on the navicular bone. Both feet will be tested and three measurements will be taken.

### Hamstring flexibility

From a lying position, your hip will be bent to 90 degrees and the knee will be slowly straightened by the researcher to a position where a stretch is felt in the back of the thigh. Measurements will be taken to assess the range of motion. Both legs will be tested and three measurements will be taken.

### Balance test

This will involve the Star Excursion Balance test. You will be asked to stand on your one leg and to reach with the opposite leg to five different marked positions. The distance will be measured to calculate your dynamic balance. Both legs will be tested and the test will be repeated three times.

### The vertical jump test

Muscle power will be assessed three times using a vertical jump test which involves squatting to the ground and jumping up as high as possible to touch the wall. Three measurements will be taken.

The testing would take approximately 30 – 45 minutes and would require you to be dressed in shorts.

You will also be asked to keep a daily logbook to keep record of your training and any running related injury. You will also be asked to rate your session on a scale from 0 - 10 according to how hard it was for you. Running related injuries will be defined as self-reported running related musculoskeletal pain of the lower limb causing a restriction of running for at least one week. This logbook must be kept for the duration of the eight-week training programme, and you will be asked to give it to the researcher for analysis once you have completed the training programme.

### **Time commitments of the study**

Completion of questionnaire	10 minutes
Biomechanical screening test	30 -45 minutes
Logbook 8 week training programme	5 min on training days

### **Confidentiality**

All information gathered in the questionnaire and screening test will be kept confidential. The screening tests will be done in private and testing will be done in a professional manner. Personal detail will only be known to the researcher and will not be used for any publications.

### **Possible Risks involved**

There are no risks involved in the measurement of flexibility or joint alignment. The risk of this maximal contraction during the vertical jump test is similar to that of performing unaccustomed exercise including painful and stiff muscles. The risk will be minimised through thorough familiarisation with all tests, and the implementation of a controlled warm up before testing procedures. In the case of injury during testing, you will be referred to an appropriate health practitioner in Port Elizabeth.

## **Significance of the study**

The study aims to identify risk factors for lower limb injuries in novice runners. This will help health professionals, athletes and trainers to be aware of potential risk factors and the possible prevention of running related injuries.

## **Benefits to the participants**

You will receive a full summary of your individual results as well as the overall findings from the study. An information booklet regarding risk factors, training methods and stretching advice for runners will also be given to you on completion of the study.

For any information or questions please feel free to contact the researcher.

### Contact Details

Rykie Greybe  
Tel 041 374 3335  
Email: [rykiebol@yahoo.com](mailto:rykiebol@yahoo.com)

Dr Theresa Burgess  
Email: [Theresa.burgess@uct.ac.za](mailto:Theresa.burgess@uct.ac.za)

Please note that UCT does offer a no-fault insurance that will cover all participants in the event that something may go wrong. This insurance will provide prompt payment of compensation for any trial-related injury according to the Association of the British Pharmaceutical Industry (ABPI) guidelines (1991). These guidelines recommend that UCT, without any 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 investigators immediately of any 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 taking part in the study.

Your right in law to claim compensation for injury where you prove negligence is not affected. Running related injuries sustained during the course of training are not considered trial related injuries and as such, will not be covered by this insurance.

I confirm that the exact procedures and possible complications of the above tests have been explained to me. I understand that I may ask questions at any time during the testing procedures. I realise that I am free to withdraw from the study without prejudice at any time, should I choose to do so. I have been informed that the personal information required by the researchers will be held in strict confidentiality. In addition, I know that the information derived from the testing procedures will remain confidential and will be revealed only as a number in statistical analyses.

I have carefully read this form. I understand the nature, purpose and procedure of this study. I agree to participate in this research project of the University of Cape Town Department of Health and Rehabilitation Sciences Division of Physiotherapy.

**Name (in full) of volunteer:**

**Signature of volunteer:**

**Date** \_\_\_\_\_

## Appendix V - Novice runner Questionnaire

Please fill this questionnaire in before the start of your training programme. It will take approximately 10 minutes of your time.

All information will be kept confidential and only be used for research purposes.

The questionnaire is voluntary.

### Section A - Personal Details

Name (optional) \_\_\_\_\_

Date of Birth: \_\_\_\_\_

Age: \_\_\_\_\_

Gender: \_\_\_\_\_

Occupation \_\_\_\_\_

**Section B – Medical history**

1. Have you ever been diagnosed with any of these disorders?

Asthma
Diabetes
Rheumatoid Arthritis
High Blood Pressure
Osteoporosis
Osteoarthritis
Cancer
High Cholesterol
Deep vein thrombosis

2. Are you on any medication (Chronic/Acute)?

Yes  No

Please specify details of the medication:

---

---

---

### Section C Injury history

1. Have you had any previous injuries?

Yes  No

2. Please indicate on the chart which area/s was injured.

Lower back
Hip
Knee
Ankle
Foot
Thigh
Buttock
Calf
Shin
Upper body

3. Please indicate the type of structure that was injured.

Muscle
Tendon
Bone
Ligament
Joint
Other (specify)

4. How was the injury treated?

Rest
Medication
Surgery
Exercises
Orthotics
Physiotherapy
Other (specify)

#### Section 4. Surgical history

1. Have you had any previous surgery to the following areas? Please tick.

Hip
Knee
Ankle
Foot
Lumbar spine

2. Please specify the type of surgery and the date of surgery.

---

---

---

---

3. Have you recovered fully after surgery?

Yes  No

#### Section 5 Current physical activity levels

1. Do you participate in any other sport?

Yes  No

2. Please specify:

1. Jogging	11. Rugby
2. Aerobics/ Step	12. Swimming
3. Martial arts	13. Cycling
4. Volleyball	14. Walking
5. Strength/ Resistance Training	15. Squash
6. Hiking	16. Tennis
7. Golf	17. Badminton
8. Canoeing	18. Netball
9. Dancing	19. Basketball
10. Skating	20. Soccer
Other:	

3. How often do you participate in this sport?

Once a week

Twice a week

More than twice a week

4. How long is a session in this sport?

Less than an hour
1-2 Hours
More than 2 hours

5. Does your occupation entail manual labour?

Yes  No

6. On average, how much time do you spend sitting a day?

> 2 hours
2 – 4 hours
4 – 6 hours
More than 6 hours

7. On average how much time do you spend doing physical work a day?

0 – 2 hours	
2 – 4 hours	
4 – 6 hours	
More than 6	

8. Do you have specific running/walking shoes?

Yes  No

9. Please tick the appropriate box.

Neutral shoes	
Anti-pronation shoes	
Minimalist/Barefoot shoes	
Not sure	

10. How many kilometres (average) have you walked/run in the shoes?

Less than 100km
100km – 500km
More than 500km

Thank you for your co-operation in completing this questionnaire.

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## Appendix VI – Daily logbook

Name: \_\_\_\_\_

Score: \_\_\_\_\_ / \_\_\_\_\_

### Daily Training Logbook Friday Week 1

**Welcome to your Training Logbook.**

**It will take approximately 5 - 10 minutes to complete this logbook.**

**Please complete all the questions accurately.**

**Once you have answered all the questions, please check your responses to make sure that all the information is correct.**

**Once you have completed the questionnaire and you are satisfied with your responses please click on the "Submit for grading" button.**

### Part 1: Training logbook

**1 Did you train today? If you answer "No", the only complete Questions 1 and 2.**

No

Yes

**2 If you did not train today, why did you not train?**

A. Today was a planned rest day

B. I did not have time to train

C. I am sick

D. I have a running related injury

**3 What has been your total running mileage (kilometers) today?**

**4 What has been your total running time (minutes) today?**

**5 How hard was your training session today?**

- A. 0 - Rest
- B. 1 - Really easy
- C. 2 - Easy
- D. 3 - Moderate
- E. 4 - Sort of hard
- F. 5 - Hard
- G. 6 -
- H. 7 - Really hard
- I. 8 -
- J. 9 - Really, really hard
- K. 10 - Just like my hardest race

**6 What type of training session did you perform today?**

- A. Flat easy run
- B. Speed training (tempo run)
- C. Hill session
- D. Interval training

**Part 2: Running Related Injuries**

**1 Did you experience a running related injury (RRI) today? A running related injury is a musculoskeletal pain of the lower limbs (lower back and below).**

- A. Yes
- B. No

**2 Have you received treatment for the condition?**

- A. Doctor (medication)
- B. Physiotherapy
- C. Chiropractor
- D. Self-medicated
- E. No, I have received no treatment

**3 How would you rate the severity of the running related injury?**

- A. 0 - No pain
- B. 1
- C. 2
- D. 3
- E. 4
- F. 5
- G. 6
- H. 7
- I. 8
- J. 9
- K. 10 - The worst pain I ever felt

**4 If you did experience a running related injury, what surface were you running on when the injury occurred?**

- A. Road
- B. Grass
- C. Beach - Soft Sand
- D. Beach - Hard Sand
- E. Running track
- F. Paving

**5 What is the location of your running related injury?**

- A. Lower back
- B. Hip
- C. Front thigh
- D. Back thigh
- E. Knee
- F. Calf
- G. Ankle
- H. Foot

## Appendix VII - Information Booklet

### Running guide for novice runners

"The hardest part of any run is the first step out the door. The hardest kilometre is usually the first one."

Physical inactivity is associated with the development of several chronic diseases, decrease longevity, loss of physical function and weight control.

#### **Benefits of running**

Weight control – Running is a fantastic workout to help to maintain a healthy weight.

Muscle and bone health – Muscle strength and flexibility is improved while the weight bearing exercise is good for your bones to reduce the risk of osteoporosis.

Disease prevention – running can prevent osteoporosis, cardiovascular disease, diabetes, metabolic syndrome and possibly cancer. Running regularly will help you live longer and have you looking great.

Stress relieve – Focusing on the task ahead and the run helps to take the mind away from stressors at work or home.

Mental health – Endorphins (natural feel-good hormones) are released while running and causes the "running high".

Improved coordination – Your body needs to keep an upright position and control the posture and movement while running. That is also way trail running is so good for you.

Confidence – The sense of accomplishment after a run no one can beat!

## **Injury**

Novice runners need adequate time for the musculoskeletal system to adapt to running.

A proper training program is essential to avoid injuries. Too much too soon can cause overuse injuries.

### **What is an overuse injury?**

An overuse injury is an injury of the musculoskeletal system resulting from the combined fatigue effect over a period of time beyond the capabilities of a specific structure that has been stressed.

### **Risk factors for overuse injuries:**

- Rapid increase in weekly distance or intensity
- Previous injuries
- Lack of running experience
- Running to compete

### **Common running injuries**

The knee is the most common area for injury in runners. The most common knee injury is patellofemoral pain syndrome (PFPS). It is thought to be due to malalignment of the patella and causes strain on the soft tissue structures around the knee. It is usually more painful with downhill running.

Other injuries are:

Iliotibial band friction syndrome	Pain on the outside of the knee. The fascia rubs against the outside knee and causes pain and inflammation.
Meniscal injuries (Knee)	Pain with weight bearing activities
Patellar tendinitis	Pain in the front of the knee due to inflammation of the patella tendon.
Plantar fasciitis	The fascia underneath the foot because tight and inflamed. The fascia helps to support the arch of the foot.
Achilles tendinitis	Pain in the Achilles area. Attaches the calf muscles Gastrocnemius and Soleus to the heel. This can become inflamed through overuse and biomechanical problems
Medial tibial stress syndrome (Shin splints)	Pain on the inside of the lower leg. Can due to tendinitis, periostitis, or bone remodeling.
Stress fractures	Pain with weight bearing and jumping activities. Can happen in the femur, tibia or feet. They are due to the repetitive impact and contraction of the muscles attached to them

### **Prevention of running injuries**

#### **Correct training methods**

A gradual increase in distance and intensity is very important. A ten percent increase in distance weekly gives the tissue enough time to adapt to the new demand and help avoid injury.

## **Proper shoes**

Running shoes should be changed every 500 – 700 km. Neutral shoes are for most runners but in severe cases of over pronation, antipronation or stability shoes may be beneficial. A thorough assessment may be necessary to decide which running shoes are the best for you.

There is a lot of debate about barefoot running or minimalistic running. If you want to try barefoot running, it should be gradually introduced. Switching to minimalist shoes your feet needs to adjust to the less support. Short distances can be introduced to help strengthen the foot muscles.

Do not wear new shoes on race day but rather wear them in first. This can prevent blisters which can alter your running style.

## **Warm up and stretching**

Brisk walking for five minutes or a slow easy run helps ease the body into the session. This will help to raise the blood pressure and increase blood-flow to the muscles. Gentle stretching can aid but do not hold a 30 second static stretch on a cold muscle before you start your run. A five to second stretch will be sufficient.

Static stretches (30 seconds) can be done at the end of a work out when you want to cool down and slowly elongate the muscle.

Stretch what is short. Do not overstretch a long and weak muscle. Ask your physiotherapist to assess your muscle length to make sure you stretch the correct way and the muscles that needs stretching.

Benefits of flexibility and stretching exercises:

- Good flexibility is essential for joint health. Tight muscles cause abnormal stresses that can cause joint deterioration.
- Improve quality of life because improves tissue elasticity which facilitates movement
- Good strength and flexibility may help prevent back pain due to improved spinal alignment.
- Reduce post exercise muscle soreness
- Improved body position and strength for sports and life.

## **Listen to your body**

Few running injuries are serious and very few problems are permanent.

Pain is a friend to be heeded, not a foe to be fought or ignored. It is a friendly warning that something is wrong, and if heeded it can be stopped early. Enduring pain doesn't equal gain. It adds up to more and more pain, until all running must cease. Time is the best healer.

### **Adequate rest**

Your body also needs time to adjust to new training methods and intensities. A weekly rest day is needed for all runners especially after a hard run or race.

When you are a beginner, most runs should be easy. One hard run a week is enough to build endurance and strength.

### **Keep a logbook**

Writing down the distance, pace and how you feel might help you see if you are training too little or too much.

### **Good nutrition**

A healthy balanced diet is necessary to keep up energy levels and to restore muscle breakdown during training. Consult a dietician for a proper diet programme.

### **Enjoy it**

Enjoy being healthy and fit. Enjoy running with friends and being outdoors!

**Good luck and happy running!**