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MUSCULOSKELETAL INJURIES AMONG ADOLESCENT CROSS-COUNTRY RUNNERS IN GAUTENG

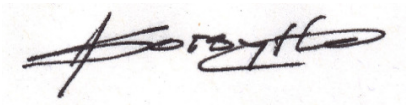
Stuart Malcolm Forsyth

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree Master of Science

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August 2014

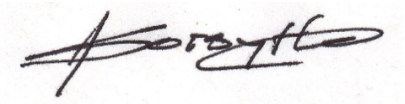
DECLARATION

I, Stuart Forsyth, declare that this research report is my own, unaided work except where otherwise specified. It is being submitted for the degree of Master of Science in the School of Therapeutic Sciences, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg. The work contained in this research report has not been submitted for any degree or examination in this or any other University.



Signed on the 25th day of August 2014.

I certify that the study contained in this thesis have been approved by the Committee for Research in Human Subjects of the University of the Witwatersrand, Johannesburg. The clearance certificate number is M110559.



Signed on the 25th day of August 2014.

Dr Aletta ME Millen (supervisor 1) Adj Prof Demitri Constantinou (supervisor 2)

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Date: ..... Date: .....

ABSTRACT

The popularity of running as a competitive sport is rising and as a result so is the prevalence of running-related injuries, not only amongst adults but also adolescents. In order to effectively manage injuries as well as to develop injury prevention programmes in adolescents it is important to establish the injury prevalence and aetiology in a South African School setting. The study therefore aimed to determine the prevalence of running-related injuries in 48 adolescent cross-country runners from two high schools in Gauteng. Secondary aims include determination of the types and location of injuries sustained, as well as the extrinsic and intrinsic risk factors associated with the injury were determined. Participants completed a questionnaire and underwent physical testing at the conclusion of the cross-country running season in order to ascertain the injuries sustained. It was determined that 58.3% of participants sustained an injury during the season, while 8.3% sustained more than one injury. Injuries were mainly overuse in nature (53.6%) and the ankle area was most frequently injured. Although 81.3% of participants participated in other sports in addition to cross-country, 63% of the injuries sustained were as a result of cross-country participation. There were no statistically significant differences between the demographic and physical characteristics or the training volumes of the participants sustaining an injury and those who did not ($p>0.05$). There was, however, a significant negative correlation between weight and the number of injuries per participant ($r = -0.4113$, $p = 0.0297$) as well as injury frequency and ground contact time ($r = -0.5147$, $p = 0.000$). No other objectively determined running related variables were associated with the risk of sustaining a running related injury ($p>0.05$). In conclusion, the result of the research report suggests that modest training volumes and most accelerometry determined running variables are not associated with the risk for sustaining a running related injury in adolescents, and neither does participation in other sports. However, low body weight and a short ground contact time and hence speed of running might predispose young athletes to running related injuries.

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LIST OF ABBREVIATIONS AND ACRONYMS

°	:	Degree
ACL	:	Anterior Cruciate Ligament
BMI	:	Body Mass Index
cm	:	Centimetre(s)
GPS	:	Global Positioning System
kg	:	Kilogram(s)
km	:	Kilometre(s)
$km.hr^{-1}$	:	Kilometres per hour
$Kg.m^{-2}$	:	Kilograms per metre squared
m	:	Metre(s)
ms	:	Millisecond(s)
min	:	Minutes
n	:	Sample Size
P	:	Probability
ppm	:	Paces per minute
s	:	Seconds
SD	:	Standard Deviation
USB	:	Universal Serial Bus

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DEFINITION OF TERMS

Incidence

The occurrence, rate or frequency of injury.

Prevalence

The proportion of the population found to have an injury (in this study), expressed as a fraction of the group.

Injury

For the purposes of this study an injury will be defined as any physical complaint sustained by a runner that is the result of cross-country running or training, irrespective of the need for medical attention or time lost from cross-country activities (Fuller et al. 2006). An injury has been defined as one that occurred during practice or competition resulting from an acute traumatic incident (Meyer & van Niekerk 2009). The definition will also include chronic and overuse injuries causing symptoms including pain or swelling during or after running cross-country (Beachy, Akau, Martinson, & Olderr 1997).

Acute Injury

An injury of sudden onset, usually as a result of trauma.

Overuse Injury

An injury that occurs over an extended period of time, also referred to as a chronic injury.

INTRODUCTION

Cross-country running is a popular sport amongst high school athletes in South Africa and is offered in schools throughout the country. Cross-country running can offer children a way to be competitive in sport whilst exercising at a high level, and assisting in developing running ability at a later age. However the participation of children and teenagers in distance running continues to be a controversial subject. Although there is current knowledge on the injuries in adult long distance runners, limited information is available on the injury profiles of adolescent long distance runners. Furthermore the prevalence of injury in other sports modalities in South Africa has been reported, but the information regarding running related injuries in cross-country runners is lacking. Although data regarding running related injuries exists from other countries, the specific demands in South African athletes are less certain. In order to develop programmes for injury prevention it is important to establish injury profiles and prevalence of running related injuries in South African adolescent cross country athletes.

Hence the present thesis was prompted by a need to address the outstanding issues regarding the injury prevalence in adolescent athletes in South Africa as well as the possible risk factors, including demographic and training volume variables that predispose athletes to these injuries. In this regard demographic and biomechanical factors have been associated with the risk of developing running related injuries in adults. In order to investigate other risk factors, not previously studied, I objectively measured accelerometry based information and it's association to risk of injury in adolescents.

The research report begins with a literature review chapter that summarises the current knowledge and incongruities in the field, which will highlight the reasons for conducting this study. The literature review chapter gives a description of running, including the aetiology

and epidemiology of related running injuries. A brief summary of the differences between adult and adolescent running injuries will then be presented. Lastly the prevention of adolescent running injuries, as well as the treatment will also be discussed. This is followed by a methodology chapter and a results chapter. Lastly the discussion chapter highlights the relevance of the findings. The discussion chapter concludes with a summary of the findings and possible future studies.

CHAPTER ONE

LITERATURE REVIEW

1.1 Introduction

Running is an activity enjoyed by many people around the world to varying degrees: from the recreational runner who enjoys being physically active to the elite athlete, who is aiming for an Olympic gold medal. Running is a fairly basic activity which does not necessarily need much expertise or equipment and can be performed by most able-bodied persons (Nerurkar 2000; Titze, Stronegger, & Owen 2005). Running at one's own leisure is an inexpensive activity which can be performed in diverse surroundings and can be as vigorous in intensity as one chooses (Titze et al. 2005). There has also been what can only be described as an explosion in the interest in recreational running which has, in turn, led to increased interest in the research and assessment of the various aspects of running itself (Novacheck 1998; Rauh & Margherita 2000; Paluska 2005; Rauh, Koepsell, Rivara, Rice, & Margherita 2006; Fredericson & Misra 2007; Lilley, Dixon, & Stiles 2011). However, as with many other sporting activities, injury threatens participation and competition in many runners. Annually there are a large number of documented injuries in runners, with reported injury rates as high as 65% (Taunton, Ryan, Clement, McKenzie, Lloyd-Smith, & Zumbo 2002).

Whilst the prevalence and causes of running injuries have been investigated in adult runners to a large extent, more recently as a result of the high performance pressure at a young age, the research interest has shifted to the younger, developing athlete (Reinking, Austin, & Hayes 2007). Athletic participation at a young age is not only associated with higher levels of physical activity later in life but is also vital in the optimal growth and development of children and adolescents (Tammelin, Näyhä, Hills, & Järvelin 2003). However, due to the

high performance demands already at a young age, this optimal development during adolescence is often jeopardised.

In this regard the emergence of athletes such as Zola Budd-Pieterse, a highly competitive athlete at a young age (Driscoll 2004), has focussed attention on the desirability of young children participating in very intensive training and competition (Noakes 2001). There is the possibility, however, that runners who aim for peak performance at a later age, such as adolescent high school cross-country runners, will become injured if they attempt to follow the training regimens of runners currently running at an elite level (Loprinzi & Brodowicz 2008). Such injuries can often be as a result of excessive training stimulus or inadequate rest (Loprinzi & Brodowicz 2008).

Children are not yet adults, and cannot be expected to maintain a competitive level of high performance for the same period of time as adults do (Noakes 2001). If there is a sudden increase in the amount of training in adolescents as well as significant increases in emotional and physical pressure, there is a potential for physical injury or damage (Meyer & van Niekerk 2009). The increased loads on the musculoskeletal system during epiphyseal plate development can result in an increased risk of injury during growth spurts in adolescence (Noakes 2001; Meyer & van Niekerk 2009). As a result the development, rather than performance should be a primary concern and adolescents should be treated differently and subject to different limitations compared to adults, in order not to force themselves to the point of injury (Noakes 2001). In this regard, what are the opportunities presented to young athletes where running is offered as an organised sports modality?

1.2 Cross-country running within South Africa

Cross-country running has grown to be a popular sport amongst high school athletes in South Africa. Cross-country running is offered as an organised sports modality in many of the high schools throughout the country with a total of 763 athletes from across the country taking part in the South African school's cross-country championships in September 2012 (SA Schools Athletcs 2012). Similarly in the United States of America cross-country running is rated as the seventh most popular school sport (Rauh et al. 2006).

Cross-country running events in South Africa are undertaken over a 4km course for junior high school participants (grades eight to 10; approximately aged 14 and 15 years) and up to 8km for those in the senior grades (grades 10 to 12; 16 to 18 years of age) (SA Schools Athletics 2012). Cross-country participants compete as individuals, in an effort to complete the required distance in the shortest possible time. At school level, however, individual completion times are combined to give a team result in order for different schools to compete against one another (SA Schools Athletics 2012). This has made cross-country competitive at a regional, provincial and national level. Clearly the competitive nature of cross-country running, similar to many other sports disciplines, places a high demand on young athletes. As with many competitive sports disciplines, young athletes are at risk for undue emotional pressure, musculoskeletal injuries and overtraining (Roach & Maffulli 2003). However, the prevalence of injuries and predisposing risk factors for injury among cross-country runners in South Africa remains uncertain.

1.3 Risks and benefits of long distance running

According to Willick and Hansen (2010) there are numerous benefits in adults to running including, but not limited to, social and personal rewards, reduced blood pressure and

cholesterol, improved cardiovascular endurance, improved weight management and mood (Willick & Hansen 2010). Nevertheless, due to its repetitive nature, running poses a risk for sustaining injuries (Willick & Hansen 2010; Lopes, Hespanhol, Yeung, & Costa 2012) which is evident from the high reported injury incidence amongst runners (Hanks & Kalenak, 1982; Louw, Grimmer, & Vaughan 2003; Paluska 2005; Mitchell J Rauh et al. 2006; Caine, Maffulli & Caine 2008; Chang, Shih, & Chen 2011; Lopes et al. 2012).

To my knowledge there is no consensus about a standard definition for a running related injury. Fuller et al. (2006) defined a running injury as 'any physical complaint sustained by a runner whilst in the act of running or training, irrespective of the need for medical attention or time lost from running itself' (Fuller et al. 2006). Additionally, others have included in their definitions interference in further running or training, grading systems and injuries that withheld the athlete from running for a one week period amongst others (van Gent et al. 2007; Lopes et al. 2012). Nevertheless a running related injury is a complex concept as it can be further classified into aetiology, the type of injury sustained, the area of injury and the mechanism of injury (Anderson 2005; Paluska 2005; Willems et al. 2006; Koh, Lee, & Healy 2007; Zifchock , Davis, Higginson, McCaw, & Royer 2008; Willick & Hansen 2010; Grau et al. 2011; Murphy 2012). Importantly, an understanding of the cause, type, incidence, prevalence, area and mechanism of running injuries is needed in order to prevent and/or manage these injuries. Hence, in the subsequent section I will highlight the factors associated with sustaining a running related injury in adults.

1.3.1 Aetiology of running related injuries

The aetiology of chronic running injuries are multifactorial, but is often classified into two main groups, namely extrinsic or intrinsic causes (Caine et al. 2008). Extrinsic factors that have reportedly been associated with the occurrence of running injuries include factors such

as training volume, shoe type or running surface (Anderson 2005; Paluska 2005; Willems et al. 2006; Koh et al. 2007; Zifchock et al. 2008; Grau et al. 2011; Murphy 2012). The intrinsic causes related to running injuries are mostly biomechanical factors such as the kinematics and biomechanics of the foot, muscular deficits and abnormal kinematics and flexibility of the musculoskeletal system, especially in the lower extremities (Anderson 2005; Paluska 2005; Willems et al. 2006; Fredericson & Misra 2007; Koh et al. 2007; Zifchock et al. 2008; Willick & Hansen 2010; Grau et al. 2011; Murphy 2012).

In this regard a number of studies aimed at investigating factors associated with the occurrence of running related injuries. Training characteristics such as distance run per week, frequency of running, the duration of running as well as the number of rest days per week have all been shown to have a direct impact on the incidence of running injuries (Rauh & Margherita 2000; Taunton, Ryan, Clement, McKenzie, Lloyd-Smith, & Zumbo 2003; van Gent et al. 2007; Chang et al. 2011; Tenforde et al. 2011; Lopes et al. 2012; Ristolainen et al. 2014). It appears that excess in each of these areas is associated with an increased risk of injury (van Gent et al. 2007; van Middelkoop, Kolkman, Van Ochten, Bierma-Zoestra, & Koes 2008; Reinking, Austin, & Hayes 2010; Chang et al. 2011). The principles of frequency, intensity and time (or distance) in the exercise training programme is known to play a large role in optimal running performance (Ferber, Hreljac, & Kendall 2009; Tenforde et al. 2011; Lopes et al. 2012). Appropriate modification of these variables may help to reduce the risk of injury while optimising training and performance (van Gent et al. 2007; Ferber et al. 2009; Reinking et al. 2010; Tenforde et al. 2011; Lopes et al. 2012). Although a large variation exists in the area of periodisation for optimal performance, little evidence exists to best adapt these principles in the prevention of injuries (Yeung & Yeung 2001). In recent years, cross-training has become a popular means of training and injury prevention for runners (Noakes 2001). Especially in running it is important to find alternative modes of

exercise that will ensure maintenance of aerobic capacity but also reduce the impact on the body (Fredericson & Misra 2007). Cross-training involves alternating different modes of exercise within a training programme in order to not overload a particular area or joint (Noakes 2001).

Other training related factors reportedly associated with sustaining a running injury are lack of training experience, training for competition, a history of previous injuries (van Mechelen 1992; Taunton et al. 2003) and the condition of running shoes (van Mechelen 1992; Yeung & Yeung 2001; Taunton et al. 2003). In addition training variables such as the implementation of a warm-up, a cool-down and/or stretching exercise prior to and following running show confounding results. Although an adequate warm-up prior to running and regular stretching is often encouraged (Fagan 1996; Anderson 2005) to my knowledge there is no evidence showing an increased risk of injury without a warm-up (Fradkin, Gabbe, & Cameron 2006) and stretching (Weldon & Hill 2003) or a decreased risk of injury after a warm-up and/or stretching (van Mechelen, Hlobil, Kemper, Voorn, & de Jongh 1993; Weldon & Hill 2003; van Gent et al. 2007; Small, Naughton, & Matthews 2008; Chang et al. 2011). However as a result of the lack of evidence in this instance and poor quality of the available studies no definitive conclusions can be drawn regarding the value of stretching and or warm-up in reducing the risk of exercise-related injury (van Mechelen 1992; Weldon & Hill 2003; Paluska 2005).

The literature on the association between running injuries and biomechanical factors such as height, malalignment, muscular imbalance, and restricted range of motion is unclear (van Mechelen 1992; van Gent et al. 2007). Nevertheless injury prevention interventions have reported that strengthening muscle groups at risk of injuries and ensuring muscle balance between agonist and antagonist muscle groups can significantly prevent the occurrence of

running-related injuries (Christopher & Congeni 2002; Ferber et al. 2009; Tenforde et al. 2011). Frequent biomechanical variables that have been associated with the 10 most common injuries in a retrospective case analysis of 2002 injuries included genu varum, genu valgus, femoral anteversion, pes planus, a high Q angle and a leg length discrepancy of more than 0.5cm. However, this data was not compared to an uninjured control group and the diagnosis of these biomechanical variations was subject to observer bias (Taunton et al. 2002). Interestingly factors such as age, BMI and gender seem not to be associated with or show contrasting results with the occurrence of running related injuries (van Mechelen 1992; Taunton et al. 2003; van Gent et al. 2007).

It is thus clear that the exact cause of many running-related overuse injuries remains unknown due to the cross sectional nature of the majority of the studies reporting running related injury incidence (Ferber et al. 2009). Furthermore the literature is riddled with small, poorly conducted studies in highly specific groups that are unable to indicate direction in this matter. Nevertheless in order to prevent running injuries effectively it is imperative to know the prevalence of running injuries as well as the most frequently injured areas. This will allow a better understanding of the factors predisposing long distance runners to injury and hence optimal prevention and treatment strategies could be developed.

1.3.2 Prevalence of running related injuries

Considering the demands of endurance running events, it is not surprising that chronic, overuse injuries are more frequently reported in runners compared to acute injuries (Taunton et al. 2002; Adirim & Barouh 2006). Acute injuries form a minor portion of reported injuries and include mainly muscular and joint sprains or strains (Taunton et al. 2002). Nevertheless, the frequency of injuries reported in running is much lower compared to contact and or

collision sports such as football (soccer), American football, gymnastics and skiing (Carty 1998; Roach & Maffulli 2003; Seto et al. 2010).

An overuse injury is defined as an injury involving the bones, muscles and or tendons that develops over a period of time due to repetitive activity (Hodson 1999). Overuse injuries become worse with continued activity at the same level as a result of repetitive micro-trauma to the injured body part and will continue unless corrected (Hodson 1999). Incidence rates of overuse and chronic running related injuries reportedly range between 6.8 and 59 injuries per 1000 hours exposure to running (Lopes et al. 2012). Others have reported injury rates of between 30% and 75% per year (van Mechelen 1992; van Gent et al. 2007). However, there is a large discrepancy in the literature regarding the injury rates as a result of variations on the specific running population studied (competitive athletes, recreational runners or age group of runners) and the specific conditions of the study (van Mechelen 1992). Nevertheless there is agreement that despite confounding variables the running injury incidence rates are very high with no clear decline in the injury rate over the last 10 years.

A recent systematic review reported 28 different running related musculoskeletal injuries, with majority of the injuries being overuse in nature (Lopes et al. 2012). From the eight studies (3500 runners) included in the analysis the most frequently reported injuries were medial tibial stress syndrome (prevalence of 9.5%), Achilles tendinopathy (prevalence between 6.2% to 9.5%) and plantar fasciitis (prevalence between 5.2% to 17.5%). In contrast a relatively large (n=2002) retrospective study reported the most prevalent injuries were patellar femoral pain syndrome, Iliotibial band friction syndrome and plantar fasciitis (Taunton et al. 2002). However the group most likely to get patellar femoral pain syndrome were recreational runners, whereas the athletes with a more extensive activity history were more likely to have medial tibial stress syndrome (Taunton et al. 2002). There seems to be

agreement that training time and volume largely determine the type of injuries reported, with plantar fasciitis, Iliotibial band friction syndrome and meniscal injury being most prevalent in athletes with higher training loads (Taunton et al. 2002; Fredericson & Misra 2007; van Middelkoop et al. 2008; Chang et al. 2011).

Studies have also reported a high prevalence of the following injuries: ankle sprains (Tenforde et al. 2011), hamstring muscle injuries (Soprano & Fuchs 2007; Tenforde et al. 2011) and tendinopathy (Lopes et al. 2012), tibial stress fractures (Roach & Maffulli 2003; Soprano & Fuchs 2007; Tenforde et al. 2011), gastrocnemius muscle injuries (Grady & Goodman 2010; Lopes et al. 2012), trochanteric bursitis (Christopher & Congeni 2002; Anderson 2005; Grady & Goodman 2010; Lopes et al. 2012), low back pain (Roach & Maffulli 2003; Soprano & Fuchs 2007; Lopes et al. 2012), costal fractures (Lopes et al. 2012), hip adductor muscle sprains (Grady & Goodman 2010; Paluska 2005; Lopes et al. 2012; Carty 1998) and meniscal injuries (Roach & Maffulli 2003; Ferber et al. 2009; Tenforde et al. 2011; Lopes et al. 2012). Even though the reported injury prevalence differ substantially amongst the various studies, as running places a large demand on the lower extremities it is not surprising there is agreement that the knee area has the highest injury incidence (7.2% to 50% of all injuries) amongst runners (Hamill, van Emmerik, Heiderscheit, & Li 1999; Taunton et al 2003; Fredericson & Misra 2007; van Gent et al. 2007; van Middelkoop et al. 2008; Ferber et al. 2009; Chang et al. 2011; Lopes et al. 2012) followed by the lower leg, the foot, the upper leg, ankle, hip and pelvis, and lower back (Hamill et al. 1999; Fredericson & Misra 2007; van Gent et al. 2007; van Middelkoop et al. 2008; Ferber et al. 2009; Lopes et al. 2012). As expected there are far fewer upper body injuries in running compared to other sports modalities (Christopher & Congeni 2002; Roach & Maffulli 2003; Anderson 2005).

There seems to be little agreement on the incidence and prevalence of running injuries in men compared to women (Ferber, McClay Davis, & Williams 2003; Paluska 2005; Reinking & Hayes 2006; Mtshali, Mbambo-Kekana, Stewart, & Musenge 2010; Chang et al. 2011). Some studies speculate that the structural differences, such as increased forefoot pronation (Reinking & Hayes 2006) and increased genu valgum (Mtshali et al. 2010) in women predisposes them to certain injuries, others found this not to be the case (Ferber et al. 2003; Chang et al. 2011). Possible reasons for this discrepancy could be the variation in the definition of a running injury used in the various studies, as well as the gender distribution in the various studies (Chang et al. 2011). Furthermore, very few studies assessed association between the biomechanical differences between men and women and running related injuries (Ferber et al. 2003). In this regard, despite numerous confounding factors, amongst various sporting modalities, women seem to have a higher prevalence of lower limb injuries compared to men (Reinking & Hayes 2006).

Nevertheless, due to large variations in study design and population including running experience, age, methodological design and running injury definition variability there is little consensus regarding the exact aetiology and prevalence of running injuries amongst adults. Even more so, very little evidence exists on the running injuries in adolescents. It becomes evident that in order to accurately describe the prevalence of injuries these above mentioned confounding factors need to be accounted for. In this regard due to the specific demands of the adolescent growing body, the increasing prevalence of high level performance at a young age and factors unique to running in adolescents the focus of this research report was the prevalence of running injuries among adolescent runners. What are the concerns for long distance running in adolescents?

1.4 Adolescents and running injuries

Similar to adults, in young athletes injuries may be as a result of overuse and overtraining (Seto, Statuta, & Solari 2010). The main causes of overuse injuries in adolescents are believed to be load, posture, technique and equipment. In running, specifically the load (repetition of training) as well as the posture is highly relevant (Hodson 1999). Moreover, due to the specific demands and factors unique to the growing body, the type of injuries and the aetiology of injuries might be different in adolescents compared to adults. In the skeletally immature athlete, the rapid bone growth and loss of flexibility predisposes adolescent athletes to injury, specifically to structures and areas left vulnerable due to growth such as the musculoskeletal system, tendon attachment sites, joint surfaces and growth plates (Adirim & Barouh 2006; Soprano & Fuchs 2007; Grady & Goodman 2010; Seto et al. 2010). Some of these injuries might result in serious musculoskeletal development problems which could have career limiting consequences, especially now that young athletes engage in greater volume and intensity of training and a higher level of competition at a younger age. Furthermore with an increase in population size there is an increase in the number of children and adolescents taking part in sports and recreational activities which, in turn, means that there is a linear increase in the number of injuries suffered within this group (Soprano & Fuchs 2007). As in many countries world-wide, gifted athletes in South Africa frequently participate and are expected to perform in multiple sports activities. Alternatively particularly talented athletes specialise in their respective sports at a young age. As a result a large demand is placed on these youngsters due to year-round training schedules for many hours per week. This increased sports participation in adolescents from an early age during the years of growth raises concern about the risk of injury. Whilst there is extensive literature related to injuries in adolescent athletes in other sports modalities (Davis 2010; Armstrong & McManus 2010), and in other countries (Bonis & Loftin 2009; Barrack, Van Loan, Rauh, & Nichols 2010), there is limited research regarding

running, particularly cross-country running, in South African adolescents. In this regard, what is the evidence for running-related injuries among adolescents?

In a large longitudinal study over 15 years, Rauh & Margherita (2000) reported an injury incidence of 13.1 injuries per 1000 running exposure hours in high school athletes. Similarly in 421 high school athletes an injury incidence of 17 per 1000 athletic exposure hours were reported (Rauh & Margherita 2000). Some studies report that girls are more likely to get injured than boys (Rauh & Margherita 2000; Rauh et al. 2006) whilst other report similar injury rates for boys and girls (Reinking et al. 2007; Bennett, Reinking, & Rauh 2012). The most frequently reported site of injury is the medial tibial area (Rauh & Margherita 2000). Similarly in collegiate cross-country athletes (18-22 years) competing at a high level the most prevalent injuries during the cross-country season were medial tibial stress syndrome, Iliotibial band syndrome patellofemoral pain syndrome and Achilles tendinopathy (Daoud et al. 2012). What are the factors predisposing adolescent cross-country runners to injury?

Although Reinking et al. (2007) showed that during a cross-country season, more than a third of the participants reported exercise related leg pain, there was no relationship between training distance and the occurrence of exercise related leg pain (Reinking et al. 2007). In this regard it is well known that a number of athletes younger than 18 years have participated in marathons without any adverse events (Roberts 2007; Seto et al. 2010). Although marathon running in children is discouraged, there is very little scientific evidence to show that training for and running a marathon is contraindicated in adolescents (Roberts 2007; Seto et al. 2010). However follow-up studies on children engaging in such distances are lacking and hence the long term developmental risks are unclear. In contrast others have reported that race distance and average distance per week are associated with repetitive injury rates (Daoud et al. 2012). Another training variable believed to predispose athletes

to injuries is the years of participation in running. In this regard there was no relationship between years of participation in running and the occurrence of exercise related leg pain (Reinking et al. 2007). Similarly, Tenforde et al. (2011) found no significant relationship between years of participation in formal running racing and the occurrence of a running related injury. From the literature the evidence that extrinsic factors and training variables are associated with a risk for a running related injury is unclear.

With regards to intrinsic risk factors, only a small number of studies have investigated the effects of biomechanical variables on the risk for sustaining a running related injury. In this regard Reinking et al. (2007) found no difference in injury prevalence in athletes with various biomechanical foot types. In contrast Bennett et al. (2012) reported that cross-country runners with navicular drop (as a measure of excessive pronation) are more likely to incur exercise related leg pain than those with no navicular drop. Foot strike patterns during running, however do affect injury prevalence as rear-foot strike runners are almost twice as likely to sustain a lower leg injury compared to forefoot strike runners (Daoud et al. 2012). Another risk factor that is strongly related to running injuries was a history of a previous running related injury (Reinking et al. 2007; Bennett et al. 2012). Similarly Rauh et al. (2006) also reported that a prior injury was the most important predictor of injury during the cross-country season. The contribution of other intrinsic factors such as age and gender in the likelihood to sustain a running related injury are contradicting and need further clarification (Rauh et al. 2006; Reinking et al. 2007; Bennett et al. 2012).

Although there is some evidence that both training variables and biomechanical factors influence the prevalence of running injuries in adolescents, it is evident that there is still considerable controversy as to the prevalence and causes of these injuries. In this regard, to my knowledge there is currently no available research on whether objectively measured

running variables, besides foot strike, contribute to the occurrence of running related injuries in adolescents. What is the current use of objectively measured running variables with accelerometry?

1.5 Accelerometry based science in running

The incorporation of science and research into sport has become increasingly popular in order to improve performance, track progress and optimise training strategies. Coaches and sports scientists constantly need to assess and monitor their athletes and training programmes, whilst incorporating scientific measures and principles, to ensure optimal performance in athletes (Tenforde et al. 2011).

During the past five years, systems with small accelerometers have been increasingly used to measure human sport motion (Houel, Dinu, Faury, & Seyfried 2011) and have become increasingly popular due to their small size, portability and simplicity (Crewther et al. 2011). These accelerometry systems incorporate perturbations in movement to describe an athlete's biomechanics and how various body parts are interacting with one another. This information is then used to estimate the changes in acceleration and mass. The accelerometer is attached to any moving object or person, and transmits information with little interference in performance, and can be used in sports-specific settings. The accelerometers act in three different planes and can couple with gyroscopes and magnetometers for increased data reporting and versatility. They have been confirmed as a valid means of assessing force, velocity and power during iso-inertial exercises (Crewther et al. 2011).

1.6 Problem Statement

Running is not just a popular recreational activity, but also a platform for competitive athletes. Cross-country running is a platform that provides the opportunity for adolescents to participate in running competitively. However the high training demands, the pressure to perform as well as the repetitive nature of running raises concerns for the risk of overuse injuries during periods of growth in youngsters. The current recommendations for training and injury prevention in childhood athletes are predominantly based on committee consensus and expert opinion, because there is very little substantial scientific data available. Although there has been some evidence of the prevalence of cross-country running related injuries in adolescents in other countries, the literature is currently lacking for overuse injuries in adolescents. Moreover, to my knowledge there is no evidence for the prevalence of injuries in cross-country running in South Africa. Furthermore effective preventative strategies to reduce the risk of injury can only be implemented if sound knowledge of the injury trends is available. Accurate and descriptive injury data allow for the identification of risk factors and preventive measures of overuse injuries, an area of study that is ripe for further investigation. Although risk factors predisposing cross-country runners have been reported, little information is available on scientific, running-related factors predisposing athletes to injury. Therefore, the aims of the present study can be summarised as follows:

1.7 Aims

The primary aim of this study is to determine the prevalence of cross-country running related injuries in adolescent cross-country runners in Gauteng. The secondary aims are to determine the types and location of injuries sustained as well as to determine the extrinsic

and intrinsic risk factors for sustaining a running related injury in adolescent cross-country runners in Gauteng.

CHAPTER TWO

METHODOLOGY

2.1 Study Design

This study used a descriptive, cross-sectional design to determine the prevalence and predisposing factors of cross-country running injuries in adolescent athletes. Participants completed a self-administered questionnaire and underwent physical testing at the conclusion of the cross-country running season in order to ascertain the injuries sustained, as well as the most common predisposing factors to injury in adolescent cross-country runners in the Gauteng Northern District league.

2.2 Participants

Forty-eight adolescent male and female cross-country runners between the ages of 14 and 18 years volunteered to participate in the study. All participants completed a detailed questionnaire and underwent physical testing to obtain anthropometric and accelerometry data.

2.2.1 Recruitment

Participants were invited to take part in the study by making initial contact with each school via email. Of the seven requested to do so, two high schools volunteered to participate in the study and all cross-country runners in the two schools were invited to participate. Of all the volunteers three subjects could not be included in the study as they did not comply with the inclusion criteria.

2.2.2 Inclusion and Exclusion Criteria

Boys and girls between the ages of 14 and 18 years were included in the study if they had participated in cross-country running during the 2011 season. All participants were participating in the Northern Gauteng district competitions.

Individuals who failed to participate in the majority of competitions (at least 5 of the 8 Central Gauteng Athletics fixtures) during the season were excluded from the study, unless they ceased to compete due to injury. Participants who were not present on the day of the study were also excluded. In the event that a participant became injured during the season they still completed the questionnaire and BMI testing but did not have to complete the run testing if this would have aggravated their injury.

2.3 Assumptions

In this study it was assumed that participants would be fair and honest in their questionnaire answers and perform in the accelerometry testing in a similar way to the way they would whilst running cross-country.

2.4 Delimitations

Activity levels of the participants may have differed in the days leading up to the testing as well as during the day of testing which would have influenced their running ability. Differences in food intake would also have influenced their weight, and therefore BMI.

2.5 Limitations

The participants were given clear and concise instructions prior to their participation in the accelerometry testing, however it is subject to intra-individual difference and observer bias. Nevertheless every effort was made to ensure that participants ran their trial at a reasonable and comfortable pace, as only one trial of 400m was given to each participant. The technique of applying the MyoTest Run to each participant was standardised by the same researcher applying the unit each time.

2.6 Place of Study

All field tests and completion of the questionnaires took place at the various schools' athletics fields on the day of testing.

2.7 Ethical Aspects

The study did not use any invasive procedures and subjects were informed that their participation was completely voluntary. The study protocol was approved by the Human Research Ethics Committee of the University of the Witwatersrand (M110559, Appendix A). Permission to conduct the study was requested from the Gauteng Department of Education, the selected schools and coaches. Permission was granted by the headmaster or head coach of cross-country at each school before the runners were contacted (Appendix B). An information leaflet was provided for each participant's parents (Appendix C) as well as the participant (Appendix D) to inform both parties on the procedures involved. An informed consent form (Appendix E) was completed by the parent or legal guardian allowing their child to volunteer for the study. The informed consent form also contained a participant assent section (Appendix F) to allow for the participant's individual permission.

Before the study all procedures were explained verbally to the participant by the researcher and the participants were offered the opportunity to ask questions. The participants who volunteered to participate in the study were free to withdraw at any time. The information and results gathered from this study are entirely confidential and the identity of the participants was protected by assigning a number to each participant. The questionnaires were coded by giving each completed questionnaire a unique numerical value, thus ensuring that the researcher could not link individual results to a respondent. The data was group analysed to ensure the confidentiality of the participants.

2.8 Measurements and Tests

All participants completed the questionnaire prior to their anthropometric variables (height and weight) were obtained. Thereafter all participants underwent the accelerometry-derived running test.

2.8.1 Questionnaire

The questionnaire used (Appendix G) for the purposes of this study was an adapted self-administered questionnaire based on a previously validated questionnaire used for adolescent basketball players in Cape Town (Louw et al. 2003). The study aims and objectives were outlined at each school and supervised by the researcher to assist with conducting the questionnaires and attending to any queries that arose.

The questionnaire was available in English only, but schools were welcome to request a translated version, if necessary. The completion of the questionnaire took no longer than 15 minutes to complete and comprised of 5 sections: personal information, frequency of running, warm-up details, general injuries sustained and treatment received. Injury

information consisted of all cross-country related musculoskeletal injuries sustained. The questionnaire was completed after the cross-country season in Gauteng, in the month of June, with no more than a week between school visits.

In order to determine the validity of the questionnaire other researchers and experts in the field of sports medicine and exercise science were consulted. The suggestions expressed by these experts were taken into account and the questionnaire was adapted based on their opinions. The reliability of the questionnaire was verified by using the test-retest method prior to administering the questionnaire to the study sample. The test-retest reliability of the questionnaire was conducted on 10 randomly selected participants where the questionnaire was repeated in a 7 day period. The Pearson's correlation coefficients for the sum of the responses in the questionnaire was 0.98 ($p<0.0001$) and the variances (mean difference ± SD) was 1.6±5.2. In addition, no significant differences between repeat measurements were evident on paired t-test analysis ($p=0.4$). In order to test the reliability of questionnaires, seven days has previously been shown to be an adequate time frame for test-retest reliability (Louw et al. 2003).

2.8.2 Anthropometric tests

Body mass

Body mass was determined with a calibrated electronic scale (Beurer, Type PS 07, Ulm, Germany) and recorded to the nearest 0.1 kilogram (kg). Participants were asked to stand in the middle of the scale, distributing weight evenly on both legs and looking straight ahead. Subjects were barefoot and clothed in light-weight clothing.

Stature

Stature was measured with a stadiometer (Medichem Solutions, Centurion, South Africa). Measurements were be taken to the nearest 0.1 centimetre (cm). Participants were barefoot with heels together and upper back, buttocks and heels against a wall. The head was placed in the Frankfurt plane. The Frankfurt plane is achieved by positioning the lower edge of the eye socket (Orbitale) in the same horizontal plane as the notch just above the tragus of the ear (Tragion). The measurement was then taken from the inferior aspect of the feet to the vertex of the skull (the highest point on the skull). The height and weight were used to determine body mass index (BMI).

2.8.3 Accelerometry running test

An accelerometer-derived running test was performed using a MyoTest RunCheck accelerometer (Pentanet, Johannesburg, South Africa). The portable accelerometer used in this study, the MyoTest Run, is an electronic system which utilises accelerometry across 3 axes. It is a compact and lightweight device which can measure parameters of running form and maintains a high level of precision (Yamauchi et al. n.d.). The MyoTest accelerometer has been shown to demonstrate a high degree of validity and reliability when used as a field testing instrument (Comstock 2011). The school's 400m athletics track was used in each case, and the length of the track confirmed using a Garmin Forerunner 410 GPS watch system (Garmin, South Africa).

The MyoTest accelerometer (the size of a matchbox) was strapped with a Velcro strap around the hips of the participant in line with both greater trochanters, in order to cause minimal interference with the natural running motion. The 'Runcheck' test was then selected from the 'Tests' section. The participant's weight and height were then entered, as well as the distance (400m) covered. Participants were then asked to run the 400m track course at

an even pace whilst wearing the accelerometer. Athletes were instructed to run at a self-selected, comfortable pace as close as possible to the pace they would maintain during competition, for the whole distance. Once the athlete had completed one full lap of the 400m track, and 3 seconds had elapsed, the test was stopped and the file saved on the unit. This test took approximately 5 minutes to administer from start to finish. The unit was then connected to the USB port of a computer and the data on the unit transferred to the MyoTest software where it could be compiled and accessed with ease.

The MyoTest accelerometer was used to quantify kinetic and kinematic variables to assess the changes in a moving body and to assess athletic performance. The data obtained was used to record the acceleration and deceleration changes in 3 dimensions when the person is moving. The force data derived was used to calculate differences between two time points, and the results recorded. The concentric and eccentric phases of a biomechanical movement were analysed because either the pushing force or landing force induced can equal the force of the body weight (Nuzzo, Anning, & Scharfenburg 2011). Time between movements was used to calculate flight time, contact time and factors such as stride length (Nuzzo et al. 2011). From the accelerometer the following data was obtained: stride frequency in paces per minute (ppm), stride length in centimetres (cm), foot contact time in milliseconds (ms), velocity in kilometres per hour ($km.hr^{-1}$), take off angle in degrees, landing angle in degrees, vertical displacement per undulation in cm, and horizontal displacement in cm.

2.9 Statistical Analysis

Statistical analysis was performed with Microsoft Office Excel (Windows Vista 2007) and GraphPad Prism version 5.02 (GraphPad Software Inc. 2009, San Diego California USA). Descriptive data are reported as means and standard deviations (±SD) unless otherwise

specified. Student's independent t-tests were performed to compare physiological variables between the injured and uninjured athletes. Pearson's and Spearman's correlations (depending whether data was parametric or non-parametric) were performed to determine the correlation between biomechanical and anthropometric data and injury point prevalence. Associations were established for categorical data and proportions using a Chi squared or Fisher's exact test. Results were considered statistically significant if $P < 0.05$. Injury prevalence was reported as a point prevalence (n/%).

CHAPTER THREE

RESULTS

3.1 Descriptive Statistics

3.1.1 Participants

The participants in this study (n=48) were high school cross-country runners and were 15.4 ± 1.6 years old (range: 14-18 years). All participants were registered as participants of the Northern District Gauteng inter-school cross-country league of 2011. There were 21 (43.75%) boys in the study group and 27 (56.25%) girls. BMI was 20.6 ± 2.73kg.m^{-2}. The physical characteristics of the 48 participants are summarised in Table 3.1. All participants completed the study.

Table 3.1: Physical characteristics of the participants

	Mean ± SD	Min	Max
Number (n)	48	-	-
Age (years)	15.4 ± 1.6	14	18
Height (cm)	169.9 ± 10.2	146	192
Weight (kg)	59.9 ± 12.6	34.8	86.6
BMI (kg.m^{-2})	20.6 ± 2.73	15.0	26.4

cm, centimetre; kg, kilogram; BMI, body mass index; kg.m^{-2}, kilogram per square metre

3.1.2 Cross-country training variables

All participants were competitive cross-country athletes who participated in at least five of the possible eight competitions during the 2011 cross-country season. All participants performed cross-country running on a weekly basis and the results of the training volume of

the participants are summarised in Table 3.2. The minimum amount of training by one participant was one hour per week whereas the maximum was 28 hours per week (median 4.5 hours per week), where the participant was training for an average of four hours each day of the week.

Table 3.2: Cross-country training variables

	Mean ± SD
Training frequency (days per week)	3.4 ± 1.5
Training duration per session (hours)	1.9 ± 0.8
Training volume (hours per week)	6.7 ± 5.7
Cross-country competitions per season	4.7 ± 1.2

Further details pertaining to the participant's cross-country participation were recorded and are detailed in Figure 3.1. The greatest proportion of the participants started participating in cross-country between the ages of 14 and 16 years (n = 18; 37.5%) and only one participant started cross-country after the age of 16 years. The majority of the participants participated in at least one other sport in addition to cross-country (n = 39, 81.3%), and nine participants participated only in cross-country running.

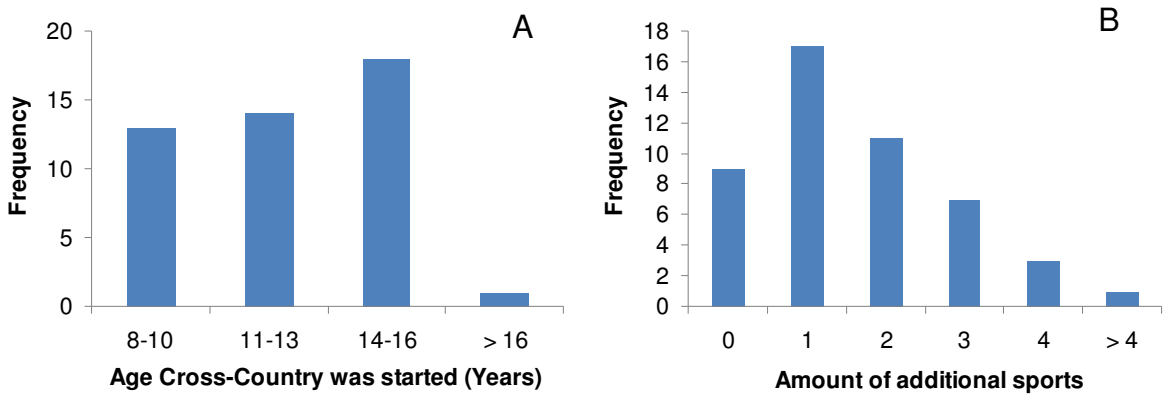


Figure 3.1: The frequency (n) of participants according to age at which cross-country was started (A) as well as how many additional sports each participant was involved in (B).

The particulars of the participants' warm-up, stretching time and other exercises performed during the warm-up are presented in Figure 3.2. Only four participants (8.3%) failed to warm-up prior to their cross-country running. The participants performed predominantly running exercises as a warm-up (n = 30; 62.5%).

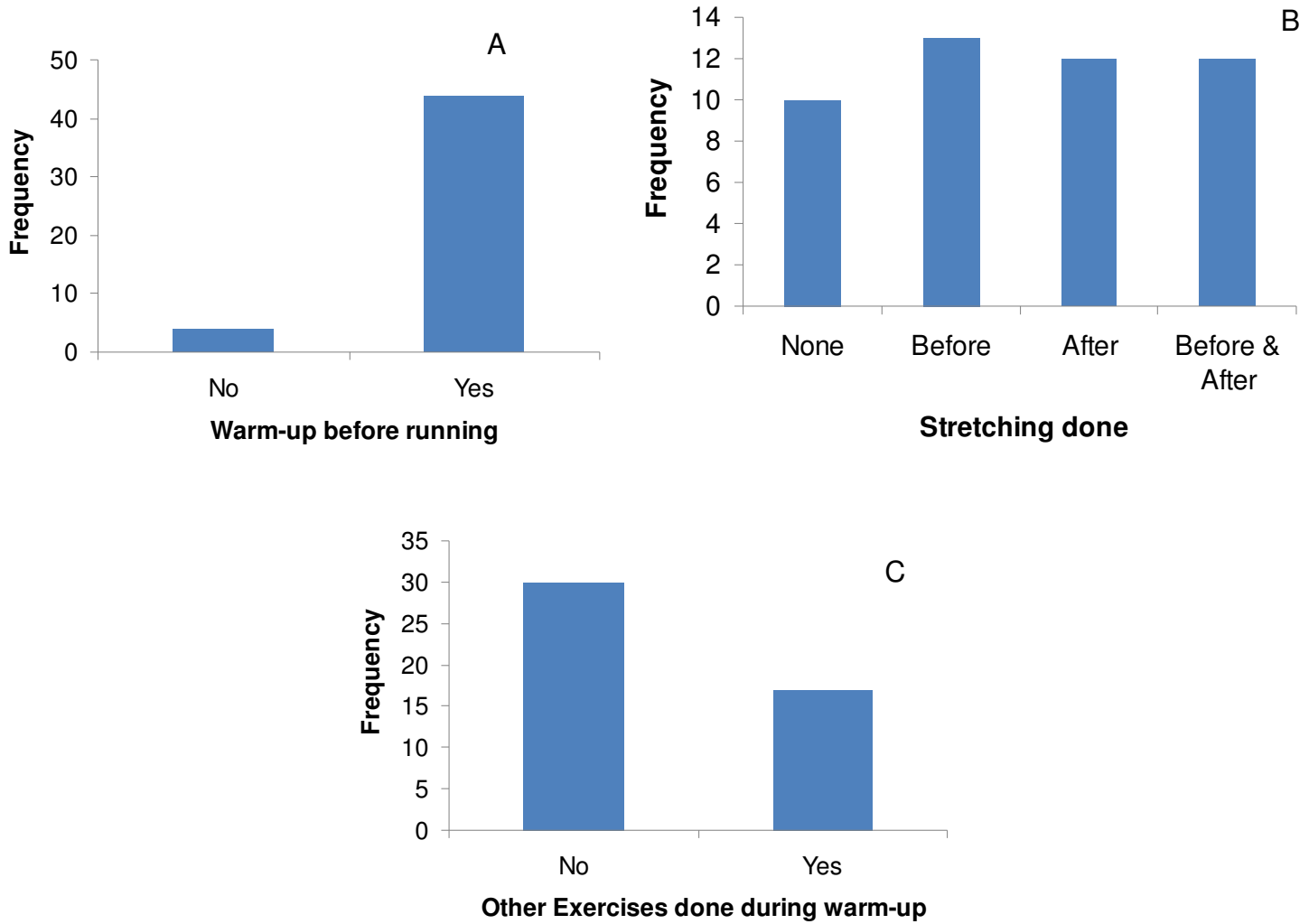


Figure 3.2: The frequency (n) of participants engaging in: a warm-up prior to running (A), stretching before and after running (B) and other exercises as a part of the warm-up (C).

3.1.3 Injury characteristics of participants

During the cross-country season a total of 36 injuries were sustained in 28 out of 48 participants (58.3%). Twenty-four participants (50%) sustained a single injury, two participants sustained two injuries (4.1%), and 2 participants sustained four injuries during the cross-country season (4.1%). The point prevalence of injuries sustained and the characteristics of the injuries are summarised in Figure 3.3.

Sixteen of the participants had first-time injuries whilst 12 reported recurrences of a previous injury within three months of the prior injury. Cross-country running was responsible for the majority of injuries (n = 23; 63%) and the ankle and foot were the most frequently injured area with 9 and 7 injuries to these structures, respectively. Other injuries (as indicated in Figure 3.3) included wrist, hand, toe and ribs or chest.

Twenty-four percent of participants did not seek therapy for treatment of their injuries and 44.8% chose to rest only (Figure 3.4). The remaining injured participants received treatment from a physiotherapist (n = 3, 10.3%) a biokineticist (n = 2, 6.8%) or a physician (n = 2, 6.8%). Other treatment methods employed by participants included use of over-the-counter topical analgesics as well as shoe orthotics. The longest time spent abstaining from sport was one week and 21 (75%) of the participants reported that their treatment plan aided injury recovery whilst the remaining participants reported that treatment was ineffective.

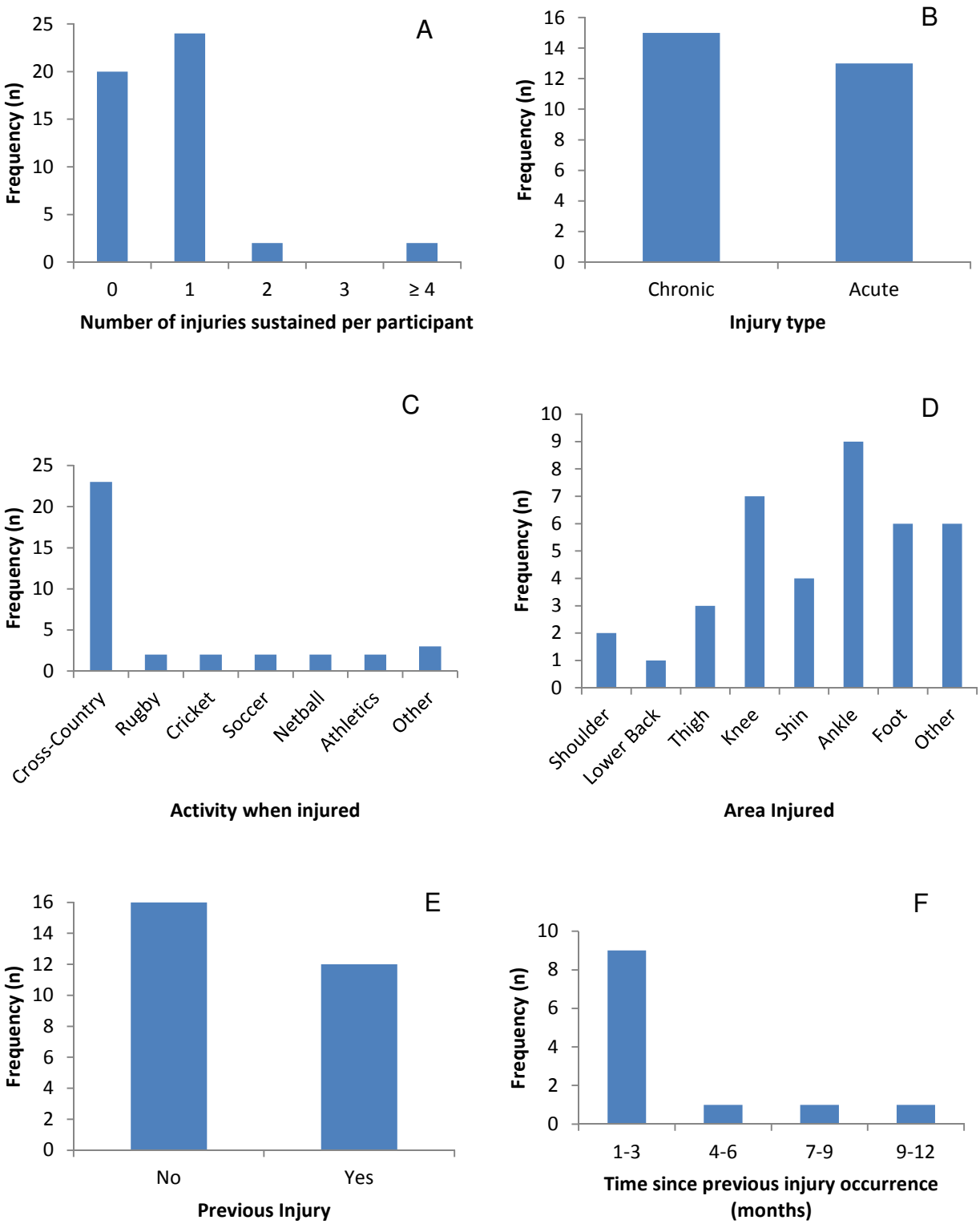


Figure 3.2: The point prevalence and characteristics of the injuries sustained during the cross-country season given as the frequency (n) of: the number of injuries sustained per participant (A), the type of injury (B), the activity that resulted in sustaining the injury (C), the area injured (D), whether previous injuries had occurred (E) and the time since the previous injury (F).

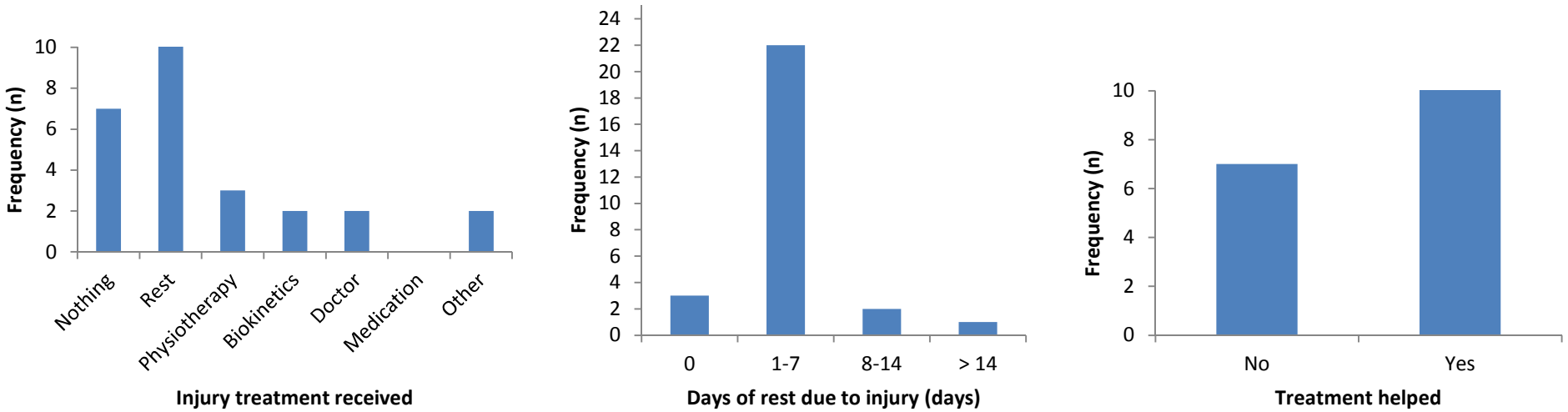


Figure 3.3: The characteristics of treatment behaviour of the participants including the nature of treatment received, the number of rest days, and success of the treatment employed.

3.2 Comparison of characteristics of injured and uninjured participants

The participants were divided into those who had sustained injuries (n = 28) and those who were injury-free (n = 20). The comparison of various characteristics of the injured and uninjured participants is presented in Table 3.3. There was no significant difference in any of the physical characteristics, training variables of running test variables between the injured and uninjured participants (all $p > 0.05$). The injured group did, however, tend to have a shorter ground contact time than the uninjured group (160.3 ± 18.17 vs 171.3 ± 20.62 ms, $p = 0.06$). Similarly the injured grouped tended to train longer per session compared to the uninjured group (2.18 ± 0.92 vs 1.72 ± 0.66 hours, $p = 0.06$). Although the uninjured group had a lower mean training volume (5.85 ± 1 hours per week) compared to that of the injured group (8.03 ± 6.3 hours per week) the difference was not significant ($p = 0.1$).

3.3 Correlations between demographic variables, training volume, running variables and injury frequency

Table 3.4 shows the correlations between the demographic variables, training volume, running variables and the number of injuries sustained in the injured group. There was no significant correlation between any of the training volume variables and the number of injuries sustained. There was however a significant negative correlation between injury frequency and weight ($r = -0.4113$, $p = 0.0297$) as well as injury frequency and ground contact time ($r = -0.5147$, $p = 0.0051$).

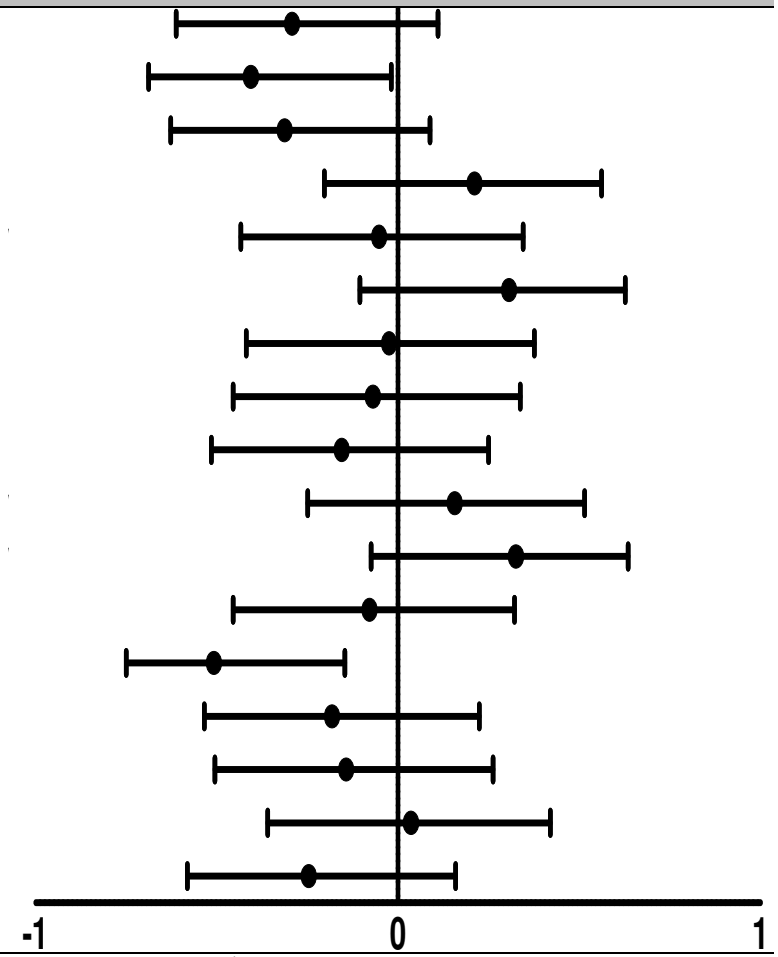
Table 3.3: Comparison of physical characteristics, training variables and running test variables of injured and uninjured participants.

Characteristics of participants	Uninjured (n = 20) Mean ± SD	Injured (n = 28) Mean ± SD	*P* value
Age (years)	15.6 ± 1.67	15.3 ± 1.66	0.692
Height (cm)	171.8 ± 8.47	168.4 ± 11.41	0.267
Weight (kg)	60.1 ± 10.31	59.9 ± 14.50	0.960
BMI ($kg.m^{-2}$)	20.2 ± 2.00	20.8 ± 3.22	0.437
Training Variables			
Competitions per season	4.5 ± 0.66	5.0 ± 1.2	0.253
Time Per Session (hours)	1.72 ± 0.66	2.18 ± 0.92	0.057
Frequency of training (days)	3.4 ± 1.50	3.5 ± 1.66	0.829
Training Volume (hours per week)	5.85 ± 1.00	8.03 ± 6.3	0.162
Warm-up (min)	14.61 ± 7.65	13.5 ± 9.47	0.701
Running test variables			
Running Time (s)	126.3 ± 24.02	122.1 ± 16.49	0.467
Velocity ($km.h^{-1}$)	11.78 ± 2.14	12.0 ± 1.66	0.657
Stride Frequency (PPM)	165.9 ± 14.76	169.6 ± 13.14	0.329
Stride Length (cm)	118.3 ± 18.38	117.85 ± 10.8	0.929
Contact Time (ms)	171.3 ± 20.62	160.3 ± 18.17	0.061
Horizontal Displacement (cm)	55.65 ± 9.13	53.1 ± 7.21	0.326
Take-off Angle (°)	16.75 ± 3.71	16.3 ± 3.30	0.631
Landing Angle (°)	72.5 ± 2.89	72.8 ± 2.16	0.675
Vertical Displacement (cm)	10.75 ± 1.63	10.4 ± 1.57	0.505

cm, centimetre; kg, kilogram; BMI, body mass index; $kg.m^{-2}$, kilogram per square metre; min, minutes; s, seconds; $km.h^{-1}$, kilometres per hour; PPM, paces per minute; ms, milliseconds; °, degrees

Table 3.4: Correlation of physiological, training volume and running variables with injury frequency

Injury frequency versus	r value	95% confidence intervals	*P* value
Height (cm)	-0.2919	-0.6124 to 0.1107	0.1317
Weight (kg)	-0.4113	-0.6872 to -0.01853	0.0297*
BMI ($kg.m^{-2}$)	-0.3093	-0.6262 to 0.08864	0.1092
Training Volume (hours)	0.1998	-0.2036 to 0.5617	0.3178
Training frequency (days)	-0.01452	-0.4334 to -0.01853	0.9415
Time per session (hours)	0.2420	-0.1045 to 0.6272	0.2239
Number of competitions	0.01198	-0.4183 to 0.3767	0.9527
Minutes of warm-up (min)	-0.08751	-0.4545 to 0.3376	0.6643
Running Time (s)	-0.1248	-0.5143 to 0.2500	0.5267
Velocity ($km.h^{-1}$)	0.1292	-0.2490 to 0.5151	0.5122
Stride Frequency (PPM)	0.2607	-0.07441 to 0.6348	0.1809
Stride Length (cm)	-0.09693	-0.4546 to 0.3216	0.6236
Contact Time (ms)	-0.5147	-0.7495 to -0.1467	0.0051*
Horizontal Displacement (cm)	-0.2029	-0.5049 to 0.2619	0.3003
Take-off Angle (°)	-0.1122	-0.5049 to 0.4203	0.5698
Landing Angle (°)	0.02760	-0.3592 to 0.4203	0.8891
Vertical Displacement (cm)	-0.1820	-0.5806 to 0.1593	0.3539



cm, centimetre; kg, kilogram; BMI, body mass index; $kg.m^{-2}$, kilogram per square metre; Min, minutes; S, seconds; $km.h^{-1}$, kilometres per hour; PPM, paces per minute; cm, centimetre; ms, milliseconds; °, degrees

* Significant ($P < 0.05$)

3.4 Associations between injury demographics and physical variables, training volume and running variables

Table 3.5 shows the association between the nature of the injury (acute or chronic) and gender and training variables. The relationship between gender and injury type (whether chronic or acute) showed that girls sustained more chronic and acute injuries than the boys did, however, this was not significant ($p>0.05$). There was no significant association between any of the training volume variables and the type of injury sustained ($p>0.05$). The relationship between training volume (in hours) and whether the injuries were chronic or acute shows that, whilst more chronic injuries were sustained with less than five training days (n = 13; 48.1%), however this was not significant. The runners participating in other sports were also not more likely to sustain either acute or chronic injuries ($p>0.05$).

Table 3.5: Association between the nature of the injury and gender and training variables

Characteristic	Categories	Injury Type	
		Acute	Chronic
Gender	**Girls**	8 (28.5%)	9 (32.1%)
	Boys	5 (17.8%)	6 (21.4%)
Training volume	**< 5 hours**	7 (25.9%)	13 (48.1%)
	5-7 hours	5 (18.5%)	2 (7.4%)
Minutes stretching	**≤ 10 min**	7 (25.9%)	9 (33.3%)
	> 10 min	6 (22.2%)	5 (18.5%)
Number of sports (in addition to cross-country)	**0-2**	12 (42.8%)	9 (32.1%)
	3-4	1 (3.5%)	6 (21.4%)
Training frequency	**1-3 days**	8 (28.5%)	7 (25%)
	4-7 days	5 (17.8%)	8 (28.5%)
Exercises performed (in addition to cross-country)	**Yes**	5 (18.5%)	5 (18.5%)
	No	8 (29.6%)	9 (33.3%)

Min, minutes

Figure 3.5 shows the association between gender, BMI and the number of injured participants. The injured boys were more likely to have a higher BMI (23.22 ± 2.55) than the girls (19.16 ± 2.55) ($p < 0.05$). Also more injuries were sustained in girls with a normal BMI than those with a high BMI ($P < 0.05$).

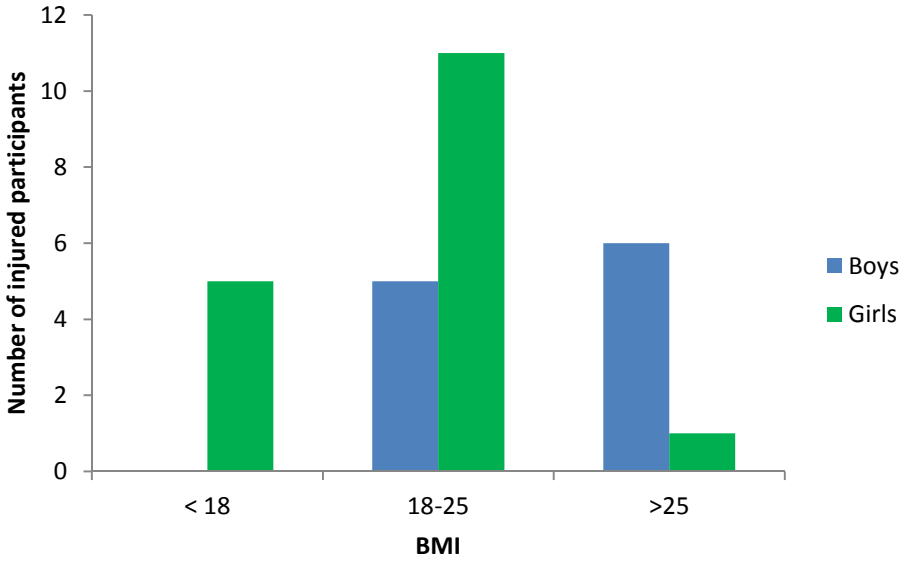


Figure 3.4: Comparison of the number of injured boys and girls as per BMI

The athletes participating in one to two other sports, in addition to cross-country, showed a trend towards being more likely to sustain a single injury (n = 15; p=0.08) than those who participated in three or more sports (n = 3) (figure 4.6). There was no association between sports participation and sustaining more than 1 injury (p>0.05)

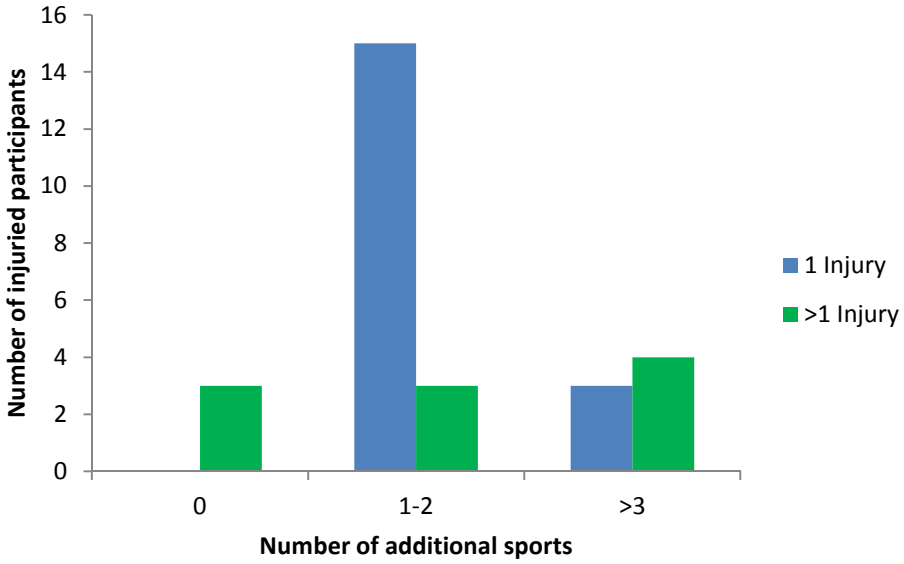


Figure 3.5: The association between the number of sports participated in and the number of injuries sustained per participant.

There was no significant association between training volume and the number of injuries sustained as presented in Figure 3.6. Even though not significant, participants training between 5 and 7 days per week were the least likely to sustain a single or multiple injuries ($p>0.05$).

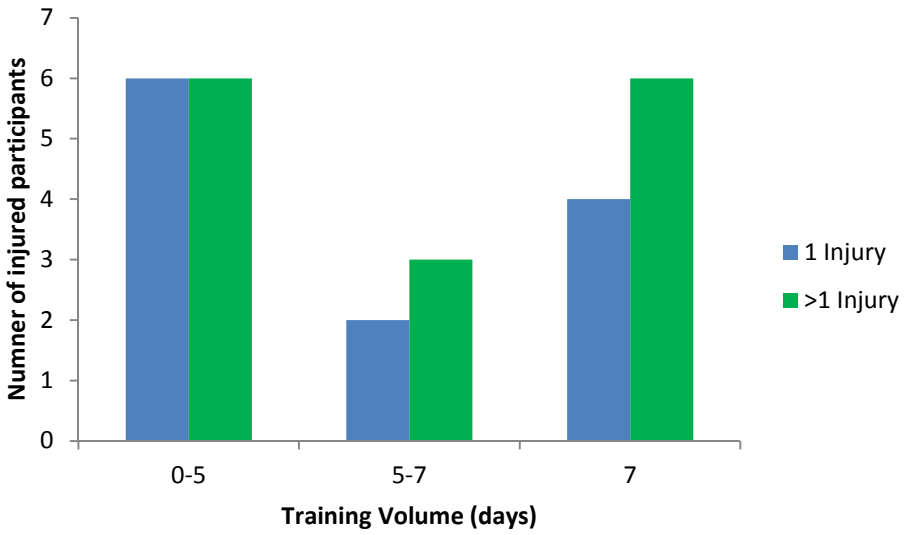


Figure 3.6: Comparison of injured participants who had one injury or more than one injury, as per training volume.

CHAPTER FOUR

DISCUSSION

4.1 Introduction

The present study examined the point prevalence of running related injury as well the factors predisposing athletes to injury amongst high school cross-country runners within Gauteng Province, South Africa. The main findings of the current study are that in 48 adolescents from two schools within the Gauteng area, 58.3% of participants sustained an injury during the cross-country season, with 8.3% sustaining more than one injury in this period. These injuries were mainly chronic in nature (53.6%) and the ankle area was injured most frequently. Although 81.3% of participants participated in other sports in addition to cross-country, 63% of the injuries sustained were as a result of cross-country participation. There were no statistically significant differences between the demographic and physical characteristic of the participants sustaining an injury and those who did not sustain an injury. There was, however, a significant negative correlation between weight and the number of injuries per participant as well as the ground contact time and injury frequency.

4.2 Injury Prevalence

To my knowledge this is the first study to contribute toward our knowledge of the prevalence of running related injuries in adolescent cross-country runners in South Africa. The current study has shown that 58.3% of participants were injured during the cross-country season. During the 4 week season, 28 runners incurred 36 injuries. The prevalence from the current study is more than the prevalence of reported injuries in previous studies of 29% (Rauh & Margherita 2000), 38.5% (Rauh et al. 2006), 38.8% (Reinking et al. 2007), and 44% (Bennett et al. 2012). However these studies only reported running-related injuries (Rauh &

Margherita 2000; Rauh et al. 2006) or running related leg pain (Reinking et al. 2007; Bennett et al. 2012). Hence, in the current study when estimating the cross-country related injuries alone the injury prevalence was 39%, which is similar to previously reported injury prevalence (Rauh & Margherita 2000; Rauh et al. 2006; Reinking et al. 2007; Bennett et al. 2012). In contrast one study reported an injury prevalence of 74% in university cross-country athletes, however these athletes were all competing at a national level (Daoud et al. 2012), whereas most other studies used younger and more recreational athletes (Rauh & Margherita 2000; Rauh et al. 2006; Reinking et al. 2007). In the current study, injuries occurred during cross-country running in the majority of injuries (63.8%) while injuries also occurred during other sports such as rugby (5.5%), cricket (5.5%), soccer (5.5%), netball (5.5%), athletics (5.5%) and other sports (8.3%).

The majority of the reported injuries were of a chronic (53.6%) rather than acute (46.4%) nature. The ankle was injured most frequently, followed by the knee, foot, shin, thigh, shoulder and lower back. The high prevalence of ankle injuries could be explained by the high frequency of acute injuries, with ankle sprain being the most frequently reported acute injury. Other reported ankle injuries included Achilles tendon injury, which is most likely due to the nature of running on uneven terrain during cross-country. Similarly others have also reported the highest injury prevalence in the lower limb with the only exception being the incidence of shin injuries in Rauh & Margherita (2000) being higher (Rauh & Margherita 2000; Rauh et al. 2006; Tenforde et al. 2011). More specifically Rauh et al. (2006) reported that the shin and the knee were the most frequently injured sites for girls and boys respectively. Studies on cross-country athletes frequently report exercise related leg pain only, and hence the specific injuries are unknown (Reinking et al. 2007; Bennett et al. 2012). In other population groups, such as marathon runners, the knee generally has a higher injury prevalence (Chang et al. 2011). This discrepancy could be as a result of the higher weekly

running mileage in marathon runners when compared to that of high school runners or due to the higher ground reaction force and stress of running a marathon on a tarred road compared to that of running off-road.

In the present study 42.8% of the injured participants reported that they have previously sustained the same injury. This is similar to other studies which have also reported that a large proportion of injuries sustained during a season is as a result of a prior injury (Rauh & Margherita 2000; Rauh et al. 2006; Bennett et al. 2012). Reinking et al. (2007) reported that 81% of athletes reporting a season incidence of running related leg pain had a history of running related leg pain, hence it is not surprising that a prior injury is one of the main predisposing risks for sustaining an injury during the season. It is speculated that poor rehabilitation techniques, muscle weakness in the previously injured area, and rushing the injured athlete's return to sport contribute to recurrence of injury (Rauh & Margherita 2000). Some of the injuries reported in the present study were older injuries (more than 4 months prior to the current injury) whilst the majority (75%) had occurred in the 1-3 months prior to the reported injury. This seems to be in agreement with the speculations that return to sport after an injury might be too soon resulting in an inadequate recovery period and or rehabilitation. More evidence for poor injury management is the lack of medical attention sought after injury occurrence. In the current study 24% of the participants did not seek any medical attention to aid their injury and continued training, while 44.8% chose to rest and ceased training. Only three participants sought medical attention from a physiotherapist, two from a biokineticist and two consulted their primary physician. Injury treatment data is not available from the studies investigating injury prevalence in adolescent or college cross-country runners. Nevertheless the potential for poor injury management in South Africa could possibly point to the lack of education of the high school runners by their respective coaches, teachers and parents, which could lead to re-injury. In order to better establish

injury management there is a need for clinical diagnosis confirmation in order to better classify injuries, and thus get a better understanding of the severity and the best course of action for treatment and management of these injuries. This could perhaps be provided for in future studies.

4.3 Possible factors predisposing cross-country runners to injury

4.3.1 Cross-country training variables

Numerous studies have reported that training variables predispose adult runners to injury (Reinking & Hayes 2006; Fredericson & Misra 2007; Reinking et al. 2010; Seto et al. 2010; Chang et al. 2011). An increase in training frequency has been shown to increase the risk of injury (Roach & Maffuli 2003; van Gent et al. 2007) possibly due to the increased repetitive load placed on the joints and muscles (Hootman et al. 2001). Others believe that it is the abrupt change in training variables rather than just the increase in duration of exercise that predisposes runners to injury (Carty 1998; Christopher & Congeni 2002). However the risk training variables pose in adolescent runners are contradicting.

In the current study we showed no association between any of the training variables and injuries. However the participants in this study were fairly homogenous regarding training variables and hence a greater variation in the level of training will be required to infer whether training does predispose adolescent cross-country athletes to injury. Nevertheless the difference in the time spent per running session (running duration) for the injured and uninjured participants did tend towards significance. The injured group spent on average, approximately 45 minutes more per training session. As a result the training volume was on average 3 hours greater in the injured group compared to the uninjured group. However this was not significantly different, but it could be due to low statistical power. It has

previously been reported that recreational runners training more than 64.4 km/week increases the risk for developing a running related injury (Macera & Pate 1989). In the current study only one participant had a very large training load and reported training for 28 hours per week (4 hours a day each day of the week). This particular participant only reported a shoulder injury, unrelated to running. Further our results showed that training more frequently (5-7 days per week) did not pose a greater risk for injury than training less (0-5 days per week). Similar to the current findings, Reinking et al. (2007) showed no differences in training variables for the injured versus uninjured athletes and that a greater training distance did not increase the risk for injury in collegiate cross-country athletes. This is supported by others who have shown no association between training duration, training volume, years of cross-country participation and sustaining a running related injury (Rauh et al. 2006; Reinking et al. 2010). In contrast, others have shown definite associations between greater training loads and injury prevalence (Rauh & Margherita 2000; Tenforde et al. 2011; Daoud et al. 2012). The possible discrepancy between these studies could be explained by the cross sectional and/or retrospective study designs that are often confounded by small sample sizes. Another possible explanation could be that, despite relatively large training volumes, this was not enough to cause chronic injuries. Clearly there is a need for a large prospective study in order to establish the relationship between training variables, such as distance and frequency, and the occurrence of a running-related injury. Also the amount of training required and tolerated by each individual is highly variable and hence the determination of a threshold value for the prevention of injuries might be an impossible task. Nevertheless, clear guidelines for safe and tolerable training loads for adolescents should be established.

Another training factor frequently believed to increase the risk for sustaining a running injury in marathon runners is a lack of running experience (Fredericson & Misra 2007). In this

regard the current study found that the age participants started cross-country were neither significantly different between the injured and uninjured nor was there any correlation between the age of participation commencement and the number of injuries sustained. Similarly prior studies have also shown no increased risk for injury as a result of running experience (Rauh et al. 2006; Plisky, Rauh, Heiderscheit, Underwood, & Tank 2007; Reinking et al. 2007; Reinking et al. 2010). However, Rauh and Margherita (2000) reported fewer injuries with greater running experience (years of participation) among high school cross-country runners. The discrepancy in the results is possibly due to a narrow range among participants as the majority of the participants (37.5%) in the present study started cross-country participation at the beginning of high school; i.e. grades 8 to10 and only one participant started in their final year of high school. There is also the possibility that, because pupils are encouraged to participate in at least one summer and one winter sport per annum they have a piqued interest in the sport at a younger age and they also do not engage in year round cross-country running training. As a result they have some running experience, but also engage in cross training throughout the year and hence a large repetitive load is not placed on these athletes.

In this regard in the current study, 19 of the runners participated in at least one other sport in addition to cross-country with only 1 of the runners participating in more than 4 sports. The most popular alternative sports were athletics followed by cricket, netball and soccer. Nine runners did not participate in additional sports. However the majority of the injuries (63.9%) were as a result of cross-country running followed by equal number of injuries from rugby, cricket, soccer, netball and athletics (5.6%, respectively). Although injury prevalence is available from many other sports modalities, it was not the focus of this research report and hence will not be discussed here (Beachy et al. 1997; Carty 1998; Rauh & Margherita 2000; Roach & Maffulli 2003; Anderson 2005; Maxfield 2010). Other studies on the injury

prevalence of cross-country running injuries did not report sports participation in other activities. Nevertheless the current results showed that participating in more than one sport additional to cross-country running did not increase the risk for sustaining more than one injury. Also participation in more additional sports (>1) did not increase the likelihood of sustaining a single injury. One possible reason for the high prevalence of a single injury in the group that did only one additional sport is likely due to the fact that the large proportion (35%) of the participants fell in this category. Nevertheless it seems that participating in various activities at a young age is not detrimental to injury risk.

Additional training variables that might predispose athletes to injury is performing a warm-up, stretching before and/or cooling down after running. Only 4 of the participants failed to warm-up prior to their running and a similar number either did not stretch at all, stretched before running or stretched after running. We showed no adverse or beneficial effects to stretching or warm-up before running or stretching and cooling down after running. None of the adolescent injury prevalence studies, to our knowledge, have investigated the effects of a warm-up or stretching on injury prevalence (Rauh & Margherita 2000; Rauh et al. 2006; Reinking et al. 2007; Reinking et al. 2010; Tenforde et al. 2011; Daoud et al. 2012). Nevertheless, adult studies have found no evidence to recommend or discourage a warm-up and or stretching in order to prevent running injuries (van Mechelen et al. 1993; Weldon & Hill 2003; Fradkin et al. 2006; van Gent et al. 2007; Small et al. 2008; Chang et al. 2011). However as a result of the lack of evidence in this instance and poor quality of the available studies no definitive conclusions can be drawn regarding the value of stretching and/or warm-up in reducing the risk of exercise-related injury (van Mechelen 1992; Weldon & Hill 2003; Paluska 2005).

In summary, from our results and others, there is no clear evidence that large training volumes, a lack of experience or the lack of a warm-up and stretching in adolescent cross-country runners predispose them to a running related injury. Nevertheless, it seems that not specialising in one sport at a young age is protective of the risk of injury. Clearly there is a need for further investigation in this matter in a large, longitudinal study.

4.3.2 Demographic and physical characteristics

There were no significant differences between the descriptive characteristics including age, height, weight and BMI of the injured versus uninjured participants. However there was a significantly negative association between weight and injury frequency. Although Grady and Goodman (2010) have reported an increased risk for injury in persons with a greater weight due to the increased ground reaction forces, others have suggested that a low BMI due to the growth spurt in children, might predispose them to injury (Carty 1998; Roach & Maffulli 2003). It is believed that the faster growth rate of bone compared to soft tissue during adolescence decreases flexibility and predisposes them to injury. However the association between weight and injury frequency could be explained by the age range of the participants and that the older boys who are more skeletally mature and thus heavier are less likely to be injured, hence the negative association between weight and injury. This is further explained by the lack of an association between BMI and injury frequency. In this regard this population was fairly homogenous for BMI (15-26.4 $kg.m^{-2}$). It is not surprising though that a larger proportion of the boys had a BMI > 20 $kg.m^{-2}$, as these were the older boys participating in other activities such as rugby which demands a more mesomorphic somatotype. Hence these athletes did not have a typical runner's physique. Although the current studies showed a higher injury prevalence in boys with a higher BMI, these were mostly acute injuries and not necessarily as a result of cross-country running. It is well accepted in the literature that persons with a higher BMI have a higher incidence (Caine et

al. 2008; Seto et al. 2010) or risk (Plisky et al. 2007; Daoud et al. 2012) of injury, while others have shown no relationship between BMI and injury (Reinking et al. 2010; Tenforde et al. 2011; Bennett et al. 2012). Rauh et al. (2006) showed in multivariate regression analysis that BMI was not a significant risk factor for injuries in either boys or girls (Rauh et al. 2006). Nevertheless the majority of the study populations had very little variation in BMI and hence there is a need for a greater range of participants in order to accurately predict the risk of injury based on BMI.

The gender comparison found very similar values for boys and girls when acute and chronic injuries were analysed. Similar to our results others have also reported no difference in injury prevalence between boys and girls (Reinking et al. 2007; Reinking et al. 2010; Bennett et al. 2012). In contrast, some have shown that girls have a higher injury prevalence (Rauh & Margherita 2000; Rauh et al. 2006; Tenforde et al. 2011) or are at greater risk for injury (Plisky et al. 2007; Daoud et al. 2012) and re-injury (Rauh & Margherita 2000) than boys. Although beyond the scope of this report, possible mechanisms that have been suggested to explain the higher risk of injury in girls include a greater quadriceps angle in girls (Rauh et al. 2006), femoral notch variation, cross-sectional diameter of the ACL, hormonal influences on injury risk, variations in lower extremity strength and flexibility, neuromuscular factors, and lower skill levels in girls (Ferber et al. 2003; Caine et al. 2008; Seto et al. 2010).

Other intrinsic variables such as posture and foot biomechanics have been associated with a risk for injury, however it was beyond the scope of this report and will not be discussed here. Nevertheless due to the cross-sectional nature of majority of the evidence, causality cannot be inferred and hence a longitudinal study to confirm the effects of anthropometry and other intrinsic factors on injury prevalence needs to be performed.

4.3.3 Running test variables

The objective accelerometry derived specific running test variables, including running time, velocity, stride frequency, stride length, horizontal displacement, take-off angle, landing angle and vertical displacement were not significantly different in the injured versus uninjured group. Moreover there was also no association between any of the running test variables and injury frequency. However, there was a trend for a significant difference in ground contact time between the two groups. Furthermore there was a significant negative correlation between ground contact time and injury prevalence. This suggests that a shorter contact time predisposed these athletes to injury. This could be explained by the increased ground reaction forces with short contact time. Grady & Goodman (2010) showed an increased force of up to 2.5 times body weight when running compared to walking and the fact that any biomechanical abnormalities are emphasised during running. Of mention, however, is the fact that Yamauchi et al. (n.d.) investigated the relationship of ground contact time to race speed and placing in elite-level half marathoners. Their findings indicate that a shorter ground contact time, when combined with an increased stride frequency, made for an overall faster runner. This makes sense as running velocity is a function of step length and frequency (Hasegawa 2007). This could explain why in the current study it was the faster runners, with the shorter contact times who were at greater risk of injury compared to their slower, longer contact time counterparts. This is supported by Daoud et al. (2012) who showed a much higher injury incidence in the more elite runners compared to others who reported lower injury prevalence in recreational runners (Rauh & Margherita 2000; Rauh et al. 2006). In addition, a faster running pace and hence shorter contact time has also been linked to a greater rate of fatigue during a race. As a consequence the fatigue alters neuromuscular output and biomechanical efficiency which predisposes athletes to injury (Meardon, Hamill, & Derrick 2011).

However, to my knowledge very little information is available on the effects of objective measured running gait and injury prevalence. Nevertheless from the current study results there might be a possible association between ground contact time and injury that could be mediated by the experience and the weight of the athlete. Further research in this promising area is evidently needed.

4.4 Study limitations

One of the major limitations of this study was the limited sample size and low statistical power, especially for a cross-sectional study design, and the sample was not representative. However other studies with a similar design have reported similar (Daoud et al. 2012) or even smaller samples sizes (Meardon et al. 2011; Ferber et al. 2003) compared to the current study. Moreover, other studies with relatively large sample sizes (n>400) showed similar results to the present study (Tenforde et al. 2011; Rauh et al. 2006). In addition athletes from only two schools were used for this study and hence confounding variables such as training techniques could not be included in the analysis. There were also more girls than boys participating in the study, however sensitivity analysis showed no differences between the training variables and running injuries of boys and girls and hence the data was pooled.

As with the nature of questionnaires, the participants might not have been completely accurate or truthful. However, the test-retest reliability showed no significant difference in the answers of 10 participants when the questionnaire was re-administered. Also with the retrospective design there is the risk of recall bias, however, previous studies have used a 12 month period for injury recall and hence adolescents should be able to accurately recall injures over a 4 week period.

Pain was also not measured as an outcome of injury and all injuries sustained by the participants would have been subjectively described.

4.5 Conclusion and future studies

In conclusion, the present study contributed towards our understanding of running related injuries in adolescent cross-country athletes in South Africa. To my knowledge this is the first study to show that there is a similar prevalence of running injuries in a South African context compared to elsewhere in the world. The present study's results have also shown that the lower limb is most frequently injured, similar to previous studies. No training volume variables or demographic variables were related to an increased risk or number of injuries, but this could be due to a relatively low training volume in this specific population. Lastly it was shown that the only variables that possibly affected the risk for sustaining a running related injury were a decreased weight and a decreased ground contact time during running. This could be indicative of a higher risk of injury with a higher level of performance, as these athletes run faster (and have a decreased contact time) and are likely to have a decreased body weight.

The results of this study raise a number of possibilities for future studies, which could include the following: a prospective long term follow up study to monitor injuries more accurately, and hence not rely on recall information from the participants, to get injury records from health care professionals in order to more carefully monitor the specific treatment received, investigation into cross-country terrain and the high rate of ankle injuries, to implement an injury prevention intervention to possibly reduce the number of injuries sustained during the cross-country season and also to monitor the training routines. Also of note is poor injury treatment and help-seeking behaviours in adolescents who did sustain any injuries during

the study. This opens the possibility of implementing education programmes not only for athletes but also for coaches and parents about injury prevention, injury management and return to sport after sustaining an injury.

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APPENDIX A: APPROVAL AND ETHICAL CLEARANCE FROM THE HUMAN RESEARCH ETHICS COMMITTEE OF THE UNIVERSITY OF THE WITWATERSRAND (M110559)

R14/49 Mr Stuart Forsyth

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M110559

NAME: (Principal Investigator) Mr Stuart Forsyth

DEPARTMENT: Centre for Health Science Education
Medical School

PROJECT TITLE: Musculoskeletal injuries among adolescent cross-country runners in Gauteng

DATE CONSIDERED: 25/03/2011

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Professor Demitri Constantinou

APPROVED BY: pp
Professor AJ Wodiwiss, Deputy Chairperson, HREC (Medical)

DATE OF APPROVAL: 03/06/2011

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

DECLARATION OF INVESTIGATORS

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

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX B: EMAIL CONFIRMATION

CONFIRMATION OF PARTICIPATION OF THE HEAD COACH PRINCIPAL FROM SCHOOLS IN GAUTENG

From: Bronwyn Watt <sport@jeppegirls.co.za>
Date: Mon, 28 Feb 2011 14:08:27 +0200
To: Stuart Forsyth<stuart@kinetics.co.za>
Subject: RE: Request for subjects for a Cross-Country injury thesis

Good Day Stuart

Your research sounds very interesting.

We have a cross-country team of approximately 25 girls who are coached by our cross-country captain of 2010.

I'm not exactly sure what you require from us for this study.
If you are just needing research subjects, I'm sure we can help you out, however we have no room in our budget if this requires any remuneration.

Regards,
Bronwyn Costine
Sport Administrator
Jeppe High School for Girls

From: Stuart Forsyth [mailto:stuart@kinetics.co.za]
Sent: 21 February 2011 10:37 AM
To: Heather Craig
Subject: Request for subjects for Cross-country injury thesis

-----Original Message-----
From: James de Wit <dewitj@4ways.co.za>
Date: Tue, 22 Feb 2011 12:26:15
To: <stuart@kinetics.co.za>
Reply-To: dewitj@4ways.co.za
Subject: Re: FW: Request for subjects for Cross-country injury thesis

Hi Stuart

We would gladly assist you with your research.

Regards

James de Wit
Head of Department - EMS
Grade 11 Tutor -2011

APPENDIX C: PARENT INFORMATION SHEET

Information Document

My name is Stuart Forsyth and I am a Biokineticist currently studying to complete my Master's degree in Biokinetics at the University of the Witwatersrand. As part of my degree I am conducting research on cross-country athletes and would like to invite your child to participate. I am investigating injuries that occur during the cross-country season and would like to invite your child to participate in this study.

Details of the study

What your child will be required to do:

- Fill in a brief questionnaire about injuries and their cross-country running. This will take approximately 15 minutes to complete.
- We will also be testing your child's height, weight, posture and running in order to assess their chance of getting an injury. This should take about 10 minutes.
- They will have to complete the questionnaire and the testing at the end of the season.

Your child will be eligible to participate if they:

- Are between 14 and 18 years of age.
- Participate in cross-country at high school level.
- Are currently competing in the Northern District inter-schools cross-country league.
- Have signed the informed consent form.
- Have asked you to complete the guardian consent form.

Rights of the participants

You and your child have the choice whether to participate in this study or not. If your child volunteers to be in this study, they may withdraw at any time without consequences of any kind. In the same way the investigator may withdraw your child from this research if circumstances arise which warrant doing so. If your child does not meet the inclusion criteria they may be withdrawn from the study and their results will not be included.

Confidentiality

The results will be kept entirely anonymous and your child's privacy respected at all times. Confidentiality will be maintained by means of assigning a number to your child's data in order to keep personal information confidential. Electronic data will be encrypted; access will only be made available to the study leader and the principal investigator. All hard copies of testing data will be

stored in a locked cabinet. The data can be made available to the participant in the form of a standardised laboratory report. No data will be revealed to other parties, it will only be published in this Master's thesis or in scientific journals. No raw data will be published and it will be reported as means of a group.

Risks and benefits of participation

There are no risks to the participants involved in this study. The benefits of participating in this study are that your child will be helping to extend the knowledge of this subject. Data will be made available to the participants upon completion of the study. In the event that your child becomes injured during the season they will still be asked to complete the second questionnaire and testing, as long as it will not aggravate their injury in any way. No remuneration will be given for participation in this study. Professional advice will be provided to your child with regards to improving any irregularities found.

If you have any questions or queries or for more information regarding any aspect of this study please feel free to contact me.

Many thanks for your participation,

Stuart Forsyth
082 336 6216
stuart@kinetics.co.za

APPENDIX D: PARTICIPANT INFORMATION SHEET

Information Document

My name is Stuart Forsyth and I am a Biokineticist currently studying to complete my Master's degree in Biokinetics at the University of the Witwatersrand. As part of my degree I am conducting research on cross-country athletes and would like to invite you to participate. I am investigating injuries that occur during the cross-country season and would like to invite you to participate in this study.

Details of the study

What you will be required to do:

- Fill in a brief questionnaire about injuries and your cross-country running. This will take approximately 15 minutes to complete.
- We will also be testing your height, weight, posture and running in order to assess your chance of getting an injury. This should take about 10 minutes.
- You will have to complete the questionnaire and the testing at the end of the season.

You will be eligible to participate if you:

- Are between 14 and 18 years of age.
- Participate in cross-country at high school level.
- Are currently competing in the Northern District inter-schools cross-country league.
- Have signed the informed consent form.
- Have asked your parents to complete the guardian consent form.

Rights of the participants

You have the choice whether to participate in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. In the same way the investigator may withdraw you from this research if circumstances arise which warrant doing so. If you do not meet the inclusion criteria you may be withdrawn from the study and your results will not be included.

Confidentiality

Your results will be kept entirely anonymous and your privacy respected at all times. Confidentiality will be maintained by means of assigning a number to your data in order to keep personal information confidential. Electronic data will be encrypted; access will only be made available to the study leader and the principal investigator. All hard copies of testing data will be stored in a locked cabinet. The data can be made available to the participant in the form of a standardised laboratory report. No

data will be revealed to other parties, it will only be published in this Master's thesis or in scientific journals. No raw data will be published and it will be reported as means of a group.

Risks and benefits of participation

There are no risks to the participant involved in this study. The benefits of participating in this study are that you will be helping to extend the knowledge of this subject. Data will be made available to the participant upon completion of the study. In the event that you become injured during the season you will still be asked to complete the second questionnaire and testing, as long as it will not aggravate your injury in any way. No remuneration will be given for participation in this study. Professional advice will be provided to you with regards to improving any irregularities found.

If you have any questions or queries or for more information regarding any aspect of this study please feel free to contact me.

Many thanks for your participation,

Stuart Forsyth
082 336 6216
stuart@kinetics.co.za

APPENDIX E: GUARDIAN CONSENT FORM

I/we, the undersigned (full names):

_____ and/or _____

(Mother / Guardian) (Father / Guardian)

Being the parent(s) / guardian(s) of:

_____ (Child's full names), aged ___ years do hereby confirm and consent to my/our child participation in the research being undertaken by Stuart Forsyth, on behalf of the University of the Witwatersrand, entitled: "**Musculoskeletal injuries among adolescent cross-country runners in Gauteng".**

I/we confirm and consent that:

- I/we understand, in full, the nature of the study and the details outlined in the information sheet provided.
- My/our child may, at his/her own assent, participate in this research study.
- My/our child's participation is entirely at my/our own risk. The researcher and affiliates accept no responsibility for theft, loss, damage to any property, or for any injury arising of whatsoever nature, regardless of the cause of the damage or injury.

Signed at _____ (place) on _____ (date)

_____

Parent / Guardian's Signature

_____

Parent / Guardian's contact number

APPENDIX F: ASSENT FORM

I, the undersigned (full names):

_____

(Participant's full names)

do hereby confirm and consent to participating in the research being undertaken by Stuart Forsyth, on behalf of the University of the Witwatersrand, entitled: "Musculoskeletal injuries among adolescent cross-country runners in Gauteng".

I confirm and consent that:

- I understand, in full, the nature of the study and the details outlined in the information sheet provided.
- I am under no obligation whatsoever to participate in this research study and do so freely.
- I understand that I am free to withdraw at any stage in the study, without any prejudice
- My participation is entirely at my own risk. The researcher and affiliates accept no responsibility for theft, loss, damage to any property, or for any injury arising of whatsoever nature, regardless of the cause of the damage or injury.
- That all information provided by myself is, to the full extent of my knowledge, is true and correct.
- I appreciate that the information is confidential
- I have made my parents/guardians fully aware of this research project and they have signed the guardian consent form.

Signed at _____ (place) on _____ (date)

_____

Participant's signature

APPENDIX G: PARTICIPANT QUESTIONAIRRE

Thank you for taking the time to participate in this study. Please use an (x) where applicable

SECTION 1: Personal Information

Age?

Male or female?

MALE	*FEMALE*

Are you left or right handed?

LEFT	*RIGHT*

At what age did you start running in cross-country events?

What other sports do you do? List below

SECTION 2: Frequency of Running

How many times a week do you train?

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*

For how long do you train for cross-country, on average, each day?

0	*<1*	*1*	*2*	*3*	*4*	*5*	*More than 5*

How often do you run in cross-country competitions per season?

0	1	2	3	4	5	More than 5

How many cross-country competitions have you run in during the last 4 weeks?

0	1	2	3	4	5	More than 5

SECTION 3: Warm-up

Do you warm-up before any running?

YES	NO

[If you answered NO you can skip to Section 4]

If **YES** above, for how many minutes do you usually warm-up?

Do you stretch during your warm-up?

YES	NO

If **YES**, do you stretch before or after your warm-up?

BEFORE	AFTER

Do you do any other exercises (like jumping, push-ups, sit-ups etc.) during warm-up?

YES	NO

If **YES**, what exercises do you do?

SECTION 4: General Injuries Sustained

Have you had any injuries (physical aches/pains/swelling) during the last month?

YES	NO

[If NO you can skip to section 5]

If you have been injured, how many times?

1	2	3	4	5	More than 5

If you know what the injury was called or diagnosed as, please describe it below:

What were you doing when you were injured?

[You can select more than one option]

CROSS-COUNTRY	
RUGBY	
HOCKEY	
CRICKET	
SWIMMING	
WATERPOLO	
SOCCER	
NETBALL	
AHTLETICS	
TENNIS	
OTHER	

If **OTHER** please write what you were doing below:

Please briefly describe how the injury occurred:

Which area/s were injured?

HEAD	
SHOULDER	
UPPER ARM	
FOREARM	
WRIST	
HAND	
UPPER BACK	
LOWER BACK	
GROIN	
THIGH	
KNEE	
SHIN	
ANKLE	
FOOT	
OTHER	

If **OTHER** please indicate the site of injury below:

Was this a sudden injury or did it happen over time?

SUDDEN	*OVER TIME*

Have you had this injury (or others listed in this questionnaire) before the last month? (Second Questionnaire)

YES	*NO*

If **YES**, when?

SECTION 5: Treatment received

What did you do to help your injury?

NOTHING - It's as bad as when it happened	
I RESTED – It's better now	
PHYSIOTHERAPY	
BIOKINETICS	
DOCTOR	

TOOK MEDICATION	
OTHER	

If **OTHER** please write below what you did:

Did you have to rest to treat the injury?

YES	*NO*

If **YES**, how long did you rest for (In Days)?

Did the treatment help?

YES	*NO*

- End of questionnaire. Thank you for your time -
