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Injury-Related Medical Encounters During the 2019 SkyRun Races and the Associated Risk Factors for Injury

A dissertation submitted in fulfilment of the requirements for the degree

M. PhysT

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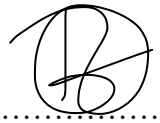
DECLARATION

I, the undersigned, declare that the dissertation hereby submitted to the University of Pretoria for the degree M. PhysT and the work contained therein is my own original work and has not previously, in its entirety or in part, been submitted to any university for a degree.



Signed ……. this 24th day of October 2023

DEDICATION

I dedicate my dissertation to my family, thank you for your never-ending support. A special thank you to my parents for all they have done for me, without them, this dissertation would not have been possible.

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I would firstly like to give my utmost appreciation to my supervisor, Dr Carel Viljoen. Thank you for your guidance and motivation throughout this process, and for sharing your knowledge with me. Thank you for never giving up on me.

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SYNOPSIS

Title: Injury-Related Medical Encounters During the 2019 SkyRun Races and the Associated Risk Factors for Injury

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Background: Trail running races often take place in remote areas, which poses a challenge for medical teams' access. Trail running is associated with a high incidence of injury, therefore more work is needed to prevent injury in this field. An understanding of the epidemiology and risk factors for injury may assist in injury prevention strategies.

Aim of the study: To determine the epidemiology, clinical characteristics, and associated risk factors for injury-related medical encounters (MEs) among trail runners who participated in the 2019 SkyRun races (38 km, 65 km and 100 km).

Design: Secondary data analysis of data collected in a descriptive, cross-sectional study.

Setting: 2019 SkyRun, hosted in the Witteberg Mountain range in Eastern Cape, South Africa.

Participants: Datasets of all participants who started ne of the 2019 SkyRun races.

Methods: Data on injury-related MEs among 412 trail runners during a high-altitude trail running event (100 km, 65 km, 38 km) were extracted for analysis. Injury prevalence (% of runners with MEs), clinical characteristics (anatomical region, body area, tissue and pathology type) and risk factors associated with injury-related MEs ($p<0.05$) were the study outcomes.

Results: The prevalence of injury-related MEs was 15.3%. Most MEs occurred in the 100 km race (92.1%). Most injuries involved the lower limb (88.9%), specifically the foot (38.4%) and the knee (23.3%). Ligament/joint capsule (13.7%), followed by muscle/tendon (11%) were the most affected tissue type. Pathology types most affected by injury were joint sprains (13.7%) and muscle strains (8.2%). Sex and age categories did not show an association with a higher risk of injury-related MEs in the 100 km race.

Conclusion: Approximately one in every six trail runners participating in a high-altitude trail running event, reported an injury-related MEs mostly affecting the lower limb. Sex and age were not associated with a higher risk of reporting an injury-related ME. These findings could contribute to the development of future injury risk management strategies for trail runners participating in high-altitude trail running events.

Keywords: Trail running, trail races, trail injuries, off-road running, medical encounters

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LIST OF ABBREVIATIONS

BMI	Body mass index
DNF	Did not finish
IOC	International Olympic Committee
Km	Kilometer
M	Meter
ME	Medical encounter
MSK	Musculoskeletal
USSF	Ultra Sports Science Foundation

CHAPTER 1

Introduction

1 INTRODUCTION

This chapter aims to provide a background to this dissertation, which will include the aims and objectives of the study, the research approach, and the significance of the study. Key terms will also be discussed. The chapter will conclude with an outline of the chapters to follow in this thesis.

1.1 BACKGROUND

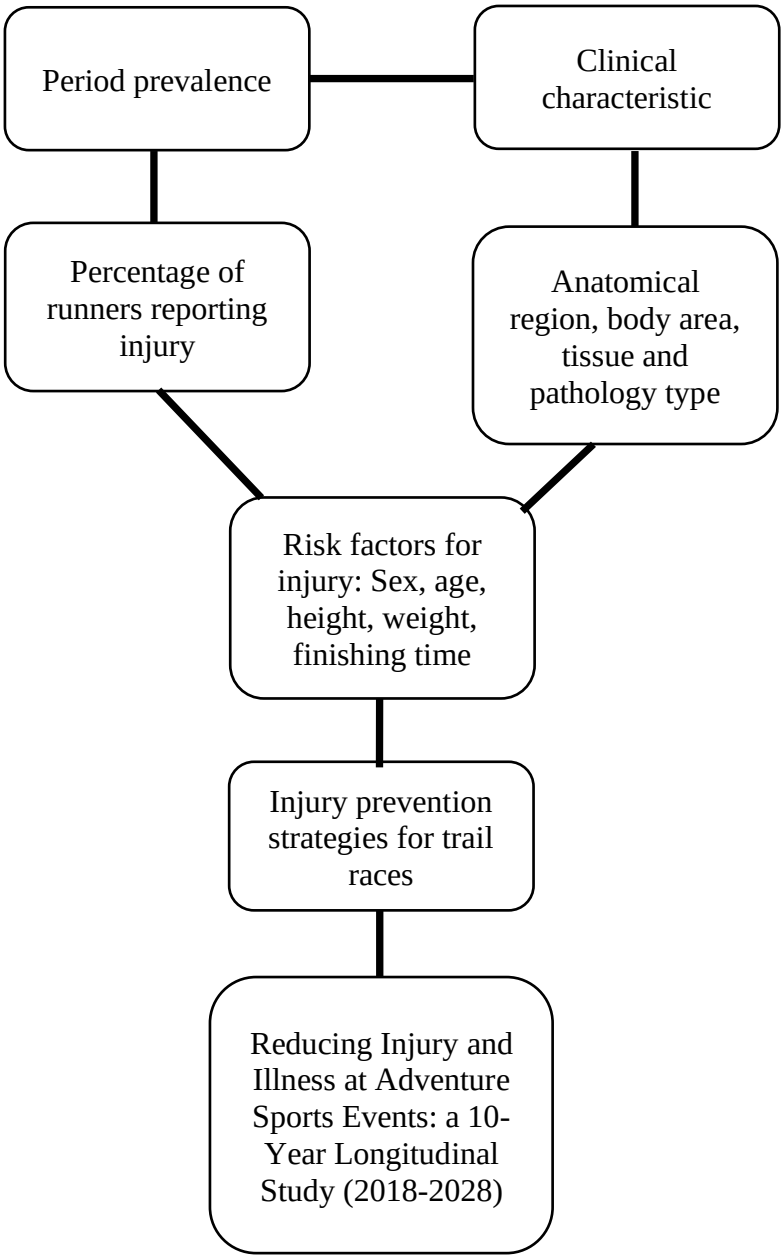
Running is a form of physical activity and there is consistent evidence that physical activity reduces the risk of major chronic diseases, specifically cardiovascular disease, breast and colon cancer, diabetes and osteoporosis (Dart et al., 2016). There are numerous types of running, of which trail running is one. Running relieves tension and improves self-image and mood, by decreasing the body's stress hormones and stimulating endorphins (Markotić et al., 2020). Trail running involves off-road running on uneven terrain (Scheer et al., 2020). Trail running takes place on inherently variable terrain, often with significant elevations and descents (ITRA, 2020). Although trail running has health benefits, it poses a high risk of injury (Viljoen et al., 2022). There is limited published literature on the injury epidemiology in trail running races, and no published literature on this topic in South Africa. This study aims to determine the epidemiology, clinical characteristics, and associated risk factors for injury-related medical encounters (MEs) among trail runners who participated in the 2019 SkyRun races (38 km, 65 km and 100 km). The 2019 SkyRun races were held in the remote terrain of the Witteberg Mountain range in Eastern Cape, South Africa. This study will determine common injuries and risk factors for race day MEs relating to demographic factors such as sex, age, height, weight as well as finishing time. Research on injury among trail runners is important to help guide injury risk management strategies among this population participating in challenging environments (Viljoen et al., 2021). This study formed part of a larger umbrella study: *"Reducing Injury and Illness at Adventure Sports Events: A 10-Year Longitudinal Study (2018 – 2028"* (REC: 460/2018).

1.2 PROBLEM STATEMENT

Currently, only eight studies globally reported on race day MEs (Buckler and O'Higgins, 2000, Dawadi et al., 2020, Graham et al., 2021, Krabak et al., 2011, McGowan and Hoffman, 2015, Scheer and Murray, 2011, Costa et al., 2016, Vernillo et al., 2016). None of these ME studies collected data on the African continent. International studies' findings, may not be

generalisable to the South African trail running population. The current study only focussed on the injury-related MEs during the 2019 SkyRun races, which address an important gap in literature. Data relating specifically to race day injuries is important for medical teams to prepare for a race. The data could further help physiotherapists design appropriate injury risk management strategies to mitigate the injury risk on race day. Without population-specific and region-specific research on injury-related MEs during trail running, injury risk management strategies tailored to South African participants may not be effective.

Figure 1: Conceptual Framework



1.3 RESEARCH QUESTION

What are the epidemiology, clinical characteristics, and associated risk factors of injury-related MEs during the 2019 SkyRun races?

1.4 AIMS

To determine the epidemiology, clinical characteristics, and associated risk factors for injury-related MEs among trail runners who participated in the 2019 SkyRun races (38 km, 65 km and 100 km).

1.5 OBJECTIVES

1.5.1 Objective 1

To determine the period prevalence of injury-related MEs (% of runners reporting injury during the race) among trail runners that participated in the 2019 SkyRun races, using data collected by medical support staff at the races.

1.5.2 Objective 2

To determine the frequency (n, %) of the injury-related MEs clinical characteristics (anatomical region, body area, pathology, and tissue type) among trail runners participating in the 2019 SkyRun races, using data collected by event medical staff at the races.

1.5.3 Objective 3

To determine the associated injury-related ME risk factors related to demography (sex, age, height and weight) and race finishing time among trail runners participating in the 2019 SkyRun races.

1.6 RESEARCH APPROACH AND STUDY DESIGN

In this project, a quantitative approach was applied whereby secondary data was analysed to address the objectives outlined in 1.5 above. The data analysed, was collected using a descriptive, cross-sectional study design. The study participants were trail runners who started the 2019 SkyRun races in the Witteberg Mountain Range in the Eastern Cape. The medical staff collected the injury-related ME data on the day of the races.

1.7 SIGNIFICANCE OF STUDY

This study focussed on the injury-related MEs during the 2019 SkyRun races. This data provided information about the prevalence of injuries during a trail race. This study aimed to determine the type of injuries sustained during the trail races, described under the following headings: anatomical region, body area, tissue and pathology type. This data is important for us to determine the most common injuries during trail races to inform future prevention strategies and incorporate them in preparation for races (González-Lázaro et al., 2021). This information was used to identify the risk factors for injury relating to demographic characteristics (sex, age, height, weight) and finishing time.

Data relating specifically to trail race day injuries is important to prepare for a race in order to minimise the risk of injury during a race, which could lead to a 'did not finish (DNF)' for the runner. Runners not able to finish a race, become a burden on the race medical staff to find, treat, and evacuate runners in remote regions. Runners put in hours of training and dedication in preparation for race days, and to not finish is a huge disappointment. Therefore, this can be minimised by strategies to decrease the risk of sustaining an injury. An improved understanding of participants' injury profiles and risk factors in participating in trail running races will guide injury risk management strategies unique to certain individuals or geographical locations.

1.8 DELINEATIONS

In this study, data was analysed that focused on all participants who voluntarily started one of the 2019 SkyRun races consisting of 38 km, 65 km and 100 km races. These races take place in the Witteberg Mountain range, Eastern Cape, and the route profiles present with off-road mountainous terrains associated with large elevation changes. The average altitude of all race categories was >2200 m. The vertical gain for the 38 km race was 2100 m, the 65 km race had 3145 m of vertical gain, and for the 100 km race, the vertical gain was 4445 m.

1.9 ASSUMPTIONS

Medical staff that collected the data captured it accurately. Participants were honest in reporting their injuries to the race-day medical staff.

1.10 DEFINITION OF KEY TERMS

The definition of key terms used in the present study are presented in Table 1 below, along with an explanation of how these terms are applied throughout the study.

Table 1: Definitions of the key terms used

Key term/concept	Definition
Anatomical region	Various areas of the human body (Rad, 2021). This study looked at the anatomical regions that the injuries affect.
Demographic factors	Details used to define characteristics of a person or a population (IGI Global, 2021). Sex, age, height, weight and finishing were the demographic factors analysed in this study.
Epidemiology	The study of the distributions and determining factors of diseases and disorders within groups of people, including the development of knowledge on how to prevent and control them (Columbia Public Health, 2020). This study looked at the distribution and determinants of the injury-related MEs among the runners who participated in the 2019 SkyRun races.
Medical encounter	An encounter between a client and a medical professional such as a physician, nurse or physiotherapist, to diagnose or treat an injury or illness (Law Insider, 2022). This study examined the encounters between the athletes and medical staff during the 2019 SkyRun races.
Pathology	The study of disease processes which involves examining the development and cause of illness, the effect of the illness on cells and the outcome of the illness (Mandal, 2021). This study aims to describe the pathology of the injuries that were encountered during the race.
Prevalence	Proportion of a population with a specific characteristic in a given time period (National Institute of Mental Health, 2022). This study examined the proportion of participants who sustained an injury in the 2019 SkyRun races.
Period prevalence	Proportion of a population with a particular disease or attribute at any time during the interval (CDC, 2012). This study examined the proportion of athletes with an injury-related ME during the 2019 SkyRun races.
Tissue	Groups of cells with a similar structure and function together to perform a specific function (Biology Dictionary, 2021). This study examined the tissue types affected by the injury-related MEs during the 2019 SkyRun races.
Trail race	A trail race is a pedestrian competition in a natural environment, with a maximum of 20% paved roads (ITRA, 2020). This study includes participants who started the 2019 SkyRun trail races.

1.11 OUTLINE OF THESIS

Chapter 2 is a literature review discussing all available literature on the epidemiology, clinical characteristics and risk factors of trail running injuries.
Chapter 3 is the original research study submitted to Sports Health Journal. In this chapter, the results of the study are displayed and interpreted.
Chapter 4 discusses the study results, which have been critically analysed and discussed with the available literature in this field.
Annexures are presented at the end of all the chapters of this dissertation.

Table 2 demonstrates in which chapters of this dissertation the aim and objectives of this study are addressed.

Table 2: Aim and objectives of the study addressed in the chapters of this dissertation

	Chapter 2	**Chapter 3**	**Chapter 4**
Aim		X	
Objective 1		X	
Objective 2		X	
Objective 3		X	
Objective 4		X	

1.12 REFERENCES

Biology Dictionary. 2021. *Tissue - Definition And Types Of Tissues* [Online]. Available: Https://Biologydictionary.Net/Tissue/ [Accessed 7 April 2022].

Buckler, D. G. & O'higgins, F. 2000. Medical Provision And Usage For The 1999 Everest Marathon. *British Journal of Sports Medicine,* 34**,** 205-9.

Columbia Public Health. 2020. *What Is Epidemiology?* [Online]. Available: Https://Www.Publichealth.Columbia.Edu/News/:~:Text=Epidemiology%20centers%20around%20the%20idea,Responses,%20interventions,%20and%20solutions. [Accessed].

Costa, R. J. S., Snipe, R., Camões-Costa, V., Scheer, V. & Murray, A. 2016. The Impact Of Gastrointestinal Symptoms And Dermatological Injuries On Nutritional Intake And Hydration Status During Ultramarathon Events. *Sports Medicine - Open,* 2**,** 1-14.

Dart, H., Nguyen, N. & Colditz, G. A. 2016. Physical Activity And Chronic Disease Prevention. *The Young Female Athlete***,** 163-179.

Dawadi, S., Basyal, B. & Subedi, Y. 2020. Morbidity Among Athletes Presenting For Medical Care During 3 Iterations Of An Ultratrail Race In The Himalayas. *Wilderness & Environmental Medicine,* 31**,** 437-440.

González-Lázaro, J., Arribas-Cubero, H. F. & Rodríguez-Marroyo, J. A. 2021. Muskuloskeletal Injuries In Mountain Running Races: A 5 Seasons Study. *Injury,* 52**,** 747-749.

Graham, S. M., Martindale, R. J. J., Mckinley, M., Connaboy, C., Andronikos, G. & Susmarski, A. 2021. The Examination Of Mental Toughness, Sleep, Mood And Injury Rates In An Arctic Ultra-Marathon. *European Journal of Sport Science,* 21**,** 100-106.

IGI Global. 2021. *What Is Demographic Factors* [Online]. Available: Https://Www.Igi-Global.Com/Dictionary/Demographic-Factors/7201#:~:Text=Characteristics%20that%20define%20a%20particular%20group%20within%20a%20population. [Accessed].

ITRA. 2020. *Discover Trail Running* [Online]. Available: Https://Itra.Run/About/Discovertrailrunning [Accessed].

Krabak, B. J., Waite, B. & Schiff, M. A. 2011. Study Of Injury And Illness Rates In Multiday Ultramarathon Runners. *Medicine and Science in Sports and Exercise,* 43**,** 2314-20.

Law Insider. 2022. *Medical Encounter Definition* [Online]. Law Insider. Available: Https://Www.Lawinsider.Com/Dictionary/Medical-Encounter [Accessed].

Mandal, A. 2021. *Types Of Pathology* [Online]. News Medical Life Sciences. Available: Https://Www.News-Medical.Net/Health/Types-Of-Pathology.Aspx [Accessed].

Markotić, V., Pokrajčić, V., Babić, M., Radančević, D., Grle, M., Miljko, M., Kosović, V., Jurić, I. & Karlović Vidaković, M. 2020. The Positive Effects Of Running On Mental Health. *Psychiatria Danubina,* 32**,** 233-235.

Mcgowan, V. & Hoffman, M. D. 2015. Characterization Of Medical Care At The 161-Km Western States Endurance Run. *Wilderness & Environmental Medicine,* 26**,** 29-35.

National Institute Of Mental Health. 2022. *What Is Prevalence?* [Online]. Nimh. Available: Https://Www.Nimh.Nih.Gov/Health/Statistics/What-Is-Prevalence#:~:Text=Definition,In%20a%20given%20time%20period. [Accessed].

Rad, A. 2021. *Anatomical Terminology* [Online]. Available: Https://Www.Kenhub.Com/En/Library/Anatomy/Anatomical-Terminology#:~:Text=Supination%2c%20inversion%2c%20eversion-,Anatomical%20regions,Pelvis%2c%20upper%20extremity%2c%20lower%20extremity [Accessed].

Scheer, B. V. & Murray, A. 2011. Al Andalus Ultra Trail: An Observation Of Medical Interventions During A 219-Km, 5-Day Ultramarathon Stage Race. *Clinical Journal Of Sport Medicine : Official Journal of The Canadian Academy Of Sport Medicine,* 21**,** 444-6.

Scheer, V., Basset, P., Giovanelli, N., Vernillo, G., Millet, G. P. & Costa, R. J. 2020. Defining Off-Road Running: A Position Statement From The Ultra Sports Science Foundation. *International Journal of Sports Medicine,* 41**,** 275-284.

Vernillo, G., Savoldelli, A., La Torre, A., Skafidas, S., Bortolan, L. & Schena, F. 2016. Injury And Illness Rates During Ultratrail Running. *International Journal of Sports Medicine,* 37**,** 565-569.

Viljoen, C., Janse Van Rensburg, D. C. C., Van Mechelen, W., Verhagen, E., Silva, B., Scheer, V., Besomi, M., Gajardo-Burgos, R., Matos, S., Schoeman, M., Jansen Van Rensburg, A., Van Dyk, N., Scheepers, S. & Botha, T. 2022. Trail Running Injury Risk Factors: A Living Systematic Review. *British Journal of Sports Medicine,* 56**,** 577-587.

Viljoen, C. T., Janse Van Rensburg, D. C., Verhagen, E., Van Mechelen, W., Tomás, R., Schoeman, M., Scheepers, S. & Korkie, E. 2021. Epidemiology of Injury And Illness Among Trail Runners: A Systematic Review. *Sports Medicine,* 51**,** 917-943.

CHAPTER 2

Narrative Review

In preparation for submission to: Sports

Grobler T., Janse van Rensburg D.C., Garnett D., Viljoen C. Gaps in the knowledge of injury-related medical encounters in trail running: A narrative review.

2 NARRATIVE REVIEW

Three recently published reviews (a systematic review, a living systematic review, and a narrative review) cover the overarching fields of injury, injury risk factors, injury prevention strategies, and rehabilitation considerations in trail running. Therefore, to not unnecessarily reproduce current scientific work, this chapter/manuscript will aim to provide an overview of existing literature on specifically race-related medical encounters (MEs) reported by trail runners. This will be done by reviewing the literature on the topics of the epidemiology of injury, injury risk factors, injury prevention strategies, and medical support challenges in the context of race MEs in trail running.

2.1 SUBMISSION DETAILS

In preparation for submission to Sports.

Title of submission:
Gaps in the knowledge of injury-related medical encounters in trail running

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Gaps in the knowledge of injury-related medical encounters in trail running: A narrative review

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ABSTRACT

Trail running is a type of physical activity that consists of running off-road. Trail running occurs on natural, variable terrain and usually has significant elevation gains. Due to the varying terrain and often high-altitude runs, there is a high risk for injury. The purposes of this narrative review are to (1) determine the prevalence of injury during trail races, (2) determine the clinical characteristics of these injuries, and (3) determine the risk factors for injury during trail races. Current literature has found the prevalence of injury on race day to range from 38% to 85% in trail runners. The lower limb, specifically the foot/toe is the most common area of injury. Skin is the most common tissue type reported, specifically blisters. Only nine studies globally have reported on injury-related medical encounters during trail races. There are limited studies that investigate injury-related MEs during trail running events and none in the African continent.

KEYWORDS

Trail running, trail races, trail injuries, off-road running, medical encounters, risk factors

1. INTRODUCTION

Physical activity has a wide range of physical and mental health benefits. Regular physical activity can help with weight control, reduce the risk of having a heart attack, lower cholesterol levels, lower blood pressure, and strengthen your bones and muscles (Center for Disease Control and Prevention, 2020). Physical activity may also improve sleep, reduce fall risk, and improve mental health and mood (Medline Plus, 2017).

Running is a form of weight-bearing exercise that helps build strong bones (Harvard Health, 2021). According to meta-analyses, running was beneficial regarding resting heart rate, body fat and body mass (Hespanhol Junior et al., 2015). The meta-analyses also found running to benefit maximal oxygen uptake, high-density lipoprotein cholesterol and triglycerides (Hespanhol Junior et al., 2015).

There are different types of running, such as track running, road running and trail running. Trail running refers to a foot race in a natural environment, such as mountains, deserts, forests, coastal areas, jungles/rainforests, grassy or arid plains, over a variety of terrains (e.g. dirt road, forest trail, single track, beach sand, etc.) with minimal paved or asphalt roads, not exceeding 20–25% of the total race course (Scheer et al., 2020).

2. METHODS AND MATERIALS

This narrative review on "Gaps in the knowledge of injury-related medical encounters in trail running" conducted using the search engine Google Scholar, and databases CINAHL, MEDLINE and SPORTdiscus. Keywords used, included: trail running, trail races, trail injuries, off-road running, and MEs. Only studies published in English were included.

3. RESULTS

3.1.Trail running

Trail running refers to all running forms not on paved roads (Wengenmeir, 2021). A trail race is defined as a race on naturally variable terrain, with a maximum of 20% paved roads (ITRA, 2020). Trail races often have significant climbs and descents (ITRA, 2020).

3.2.Benefits of trail running

Trail running improves cardiovascular stamina, core and leg muscle strength, balance and agility (Sebor, 2015), and mood and mental well-being (Specter, 2017). Trail running increases brain activity, improves every element of fitness, is good for mental health and is not as hard on your joints as pavement/tarmac (Grewcock, 2019). Trail running occurs on various terrains, stimulating strength development in muscles, including the smaller muscles that provide stability and support (Roy, 2015). Trail running also improved proprioception, balance, agility and mental focus (Roy, 2015). Although trail running has health benefits, its risk of injury is high (Viljoen et al., 2022).

3.3.Injury in trail running

Trail running poses physical demands on participants and events often take place in remote areas where access to medical care and resources are limited (Hoffman et al., 2014). A few studies have been done on trail running injuries and risk factors but have not included long term follow-up periods, including injuries that occurred during races and/or training-related injuries. According to the authors knowledge, twelve studies globally report on injuries during trail events (Buckler and O'Higgins, 2000, Costa et al., 2016, Dawadi et al., 2020, González-Lázaro et al., 2021, Graham et al., 2021, Graham et al., 2012, Hoffman and Stuempfle, 2015, Krabak et al., 2011, McGowan and Hoffman, 2015, Scheer and Murray, 2011, Scheer et al., 2014, Vernillo et al., 2016). Only eight of these studies report on injury-related MEs during trail events (Buckler and O'Higgins, 2000, Dawadi et al., 2020, Graham et al., 2021, Krabak et al., 2011, McGowan and Hoffman, 2015, Scheer and Murray, 2011, Vernillo et al., 2016, Costa et al., 2016). Of these studies, only three reported on the prevalence of injury-related MEs (Dawadi et al., 2020, Graham et al., 2021, Scheer and Murray, 2011), one reported on the anatomical region of injury (Krabak et al., 2011), two reported on body area of injury (Krabak et al., 2011, Scheer and Murray, 2011). No study reported on tissue type, but focused mainly on pathology type (Dawadi et al., 2020, Graham et al., 2021, Vernillo et al., 2016, Krabak et al., 2011). However, a few studies reported musculoskeletal (MSK) and dermatological injuries as a percentage of total MEs (including illness-related MEs) (Dawadi et al., 2020, Vernillo et al., 2016, Krabak et al., 2011, Scheer and Murray, 2011, McGowan and Hoffman, 2015, Costa et al., 2016). Below follows a discussion on injuries in trail running, finally narrowed down to only injury-related MEs during trail events.

3.3.1. Prevalence of injury in trail running

A living systematic review found the overall injury prevalence variable with results ranging from 1.3%-90% (Viljoen et al., 2022). This systematic review included studies that investigated trail running injuries on race day as well as studies that investigated training-related injuries.

A study conducted on muscle cramping during a 161 km ultramarathon through the Sierra Nevada Mountains in Northern California found that 14.3% of runners reported muscle cramping at some point during the race (Hoffman and Stuempfle, 2015). Near muscle cramping was reported by 26.8% of runners (Hoffman and Stuempfle, 2015).

Three studies reported the prevalence of injury-related MEs during trail events (Dawadi et al., 2020, Graham et al., 2021, Scheer and Murray, 2011). The Manaslu Trail Race is a seven-stage, 212 km race with an altitude between 730-5160 m (Dawadi et al., 2020). The total prevalence of injury-related MEs during three iterations (2014, 2015 and 2016) of this Manaslu Trail Race was 38% (Dawadi et al., 2020). The Arctic ultramarathon is a three-day, 120 mile race in Canada's Yukon and North West Territories areas (Graham et al., 2021). The temperatures in this race ranged between -20 and -6 degrees Celsius (Graham et al., 2021). The prevalence of injury-related MEs during this race was 85% (Graham et al., 2021). The Al Andalus Ultra Trail is a five-day stage race in southern Spain, covering 219 km (Scheer and Murray, 2011). The temperatures during this race, in 2010, ranged between 32 and 37 degrees Celsius. In 2010, the prevalence of injury-related MEs was 56.5% (Scheer and Murray, 2011).

The differences in ranges can be attributed to the different weather conditions and route profiles between the races. The Arctic ultramarathon had very cold and windy weather conditions, causing injuries such as frost injury (Graham et al., 2021). The Arctic ultramarathon only had 12 participants (Graham et al., 2021), therefore runners could be monitored more closely which is a possible reason for the prevalence of injury to be higher. Bigger races with more participants such as the Manaslu Trail Race and the Al Andalus Ultra Trail had more participants, so some runners may not have reported their injuries to medical staff on the day of races, as the participants could fear being medically disqualified (Viljoen et al., 2021).

3.3.2. Clinical characteristics

For the purpose of this review, clinical characteristics will be divided into anatomical region of injury, body area, pathology and tissue type as suggested by the International Olympic

Committee (IOC) consensus statement on recording and reporting epidemiological injury/illness data in sports (Bahr et al., 2020).

3.3.2.1.Anatomical region

In a recent systematic review summarising trail running literature, the most reported anatomical region of injury was the lower limb, found in 83.3% of studies (Viljoen et al., 2022). Trunk injuries were reported in 44.4% of studies, followed by upper limb injuries reported in 33.3% of studies (Viljoen et al., 2022).

For race day injuries, a study of 36 mountain running races over five consecutive seasons found that most injuries occurred in the lower limb (78%) (González-Lázaro et al., 2021). Only one study reported on the anatomical region for injury-related MEs during a trail race, which found that 92.6% of injuries in the RacingThePlanet, seven day, staged, 240 km ultramarathon race from 2005 to 2006 occurred in the lower limb (Krabak et al., 2011). The lower limb being the most reported anatomical region of injury could be because the joints and soft tissue structures in the lower limb are under the most strain during running.

3.3.2.2.Body area

A recent review identified the most common injured body area reported on is the toe/foot (55.6%), followed by the ankle (50.0%) and the hip/groin (50.0%) (Viljoen et al., 2022).

The body area mostly affected by muscle cramps during a 161 km ultramarathon through the Sierra Nevada Mountains was the calf, followed by the quadriceps and the hamstrings (Hoffman and Stuempfle, 2015). The most frequent body area injured was the ankle (32%), followed by the knee (14%) and the foot/toe (11%), during 36 mountain races over five consecutive seasons (González-Lázaro et al., 2021). This study only looked at MSK injuries, so skin disorders were not considered. The injuries in this study were self-reported on by the participants.

For injury-related MEs, only two studies reported on the body area of injury (Krabak et al., 2011, Scheer and Murray, 2011). The majority of the injuries in the RacingThePlanet, 4 Desert Series ultramarathon races from 2005 to 2006, were in the foot (73.7%), then the lower leg (8.6%), followed by the ankle (4.9%) and then the knee (3.5%) (Krabak et al., 2011). During

the Al Andalus Ultra Trail, knee injuries were the most common MSK ME (9.1% of the total MEs), but foot blisters accounted for 33.3% of the total MEs (Scheer and Murray, 2011).

3.3.2.3.Tissue type

In a recent systematic review, superficial tissue/skin is reported as the most common tissue injury in literature (72.2%), followed by muscle/tendon injuries (44.4%) and ligament/joint capsule injuries (38.9%) (Viljoen et al., 2022).

Most of the injury-related ME studies reported on a percentage of MSK injuries and a percentage of skin-related disorders in general. During the 2014 to 2016 Manaslu Trail, 17% of encounters were MSK (Dawadi et al., 2020). During the 65km Vigolana Trail in 2014, MSK injuries accounted for 32.8% of ME, and skin-related disorders accounted for 16.9% of MEs (Vernillo et al., 2016). In The RacingThePlanet races, 18.5% were MSK injuries and 71.4% were skin-related injuries (Krabak et al., 2011). During the 219km Al Andalus Ultra Trail, 22.2% of the MEs were for MSK injuries, and 45.5% were for dermatological injuries (Scheer and Murray, 2011). During two iterations of the 161km Western States Endurance Run, MSK injuries accounted for 31.7% of MEs (McGowan and Hoffman, 2015). A dermatological injury was reported by 89% of ultramarathon runners during a multi-stage ultramarathon over four days and 14% in a 24-hour race (Costa et al., 2016).

Dermatological injuries can occur from excessive frictional forces (Costa et al., 2016), as well as from the environment that trail running takes place in. Dermatological injuries are higher in multiday races as participants are exposed to those frictional forces for longer periods.

3.3.2.4.Pathology type

According to a systematic review, the most common pathology types reported are blisters (50.0%) followed by joint sprains (44.4%) and tendinopathies (38.9%) (Viljoen et al., 2022). Bone fractures and concussions were reported in two studies each (11.1%) and a dislocated metacarpophalangeal joint, frost injury, joint subluxation and tendon rupture were each reported in one study (5.6%) (Viljoen et al., 2022).

Eleven participants, all male, competed in a seven-day staged race, covering a total of 150 miles in the Gobi Desert. All subjects had minor abrasion injuries, mostly on the lower limb. All participants (100%) required medical care for skin or soft tissue damage. The most common

injury was blisters, 100% of the participants, specifically on the feet. Other common complaints were shin pain, Achilles tendon pain and pain or stiffness in knees (Graham et al., 2012). During the Al Andalus Ultimate Trail, over five days in 2010 and 2011, 76% of participants had blisters after day 4 of running (Scheer et al., 2014).

Specifically for MEs on race day, plantar fasciitis (28.6%) and ankle sprains (28.6%) were the most common MSK injuries in ultra-runners competing in the Vigolana Trail race (65km), and foot blisters were the most common dermatological injury (52.8%) (Vernillo et al., 2016). Tendonitis was found to be the most common MSK injury during a seven-day stage race (240km) (Krabak et al., 2011). Nine out of 22 (40.9%) MSK MEs involved patellofemoral pain, followed by 22.7% for ankle inversion injuries in a five-day ultramarathon stage race (reference). However, blisters accounted for 33.3% of the total MEs and were the most common injury-related ME (Scheer and Murray, 2011). During an Arctic ultramarathon, abrasions were reported by 58% of the participants, hip MSK pain was reported by two out of a total of 12 participants (16.7%), two participants reported blisters and two participants reported frost bite injury (Graham et al., 2021). During the Everest Marathon in 1999, 65 runners started the race. The following injuries were sustained: one ingrown toenail, one dislocated metacarpophalangeal joint, one dog bite, one participant sustained cuts on his/her head from a stone that had fallen, one ankle ligament sprain, one trochanteric bursitis, one semimembranous bursitis, three participants struggled with Achilles tendinitis and seven participants needed medical attention for foot blisters (Buckler and O'Higgins, 2000).

Blisters are the most common pathology type reported. This is likely as a result of friction of shoes and socks against skin (Mailler and Adams, 2004), which is exacerbated by the irregular terrain of trail running.

3.4.Associated injury risk factors in the trail running races

There is evidence that age, sex, body mass index (BMI), running distance and running frequency per week are not associated with risk of injury in trail running (Viljoen et al., 2022).

During a multi-stage ultramarathon, no significant difference in the incidence of dermatological injuries was found between sexes and speed of running, however, sustaining a dermatological injury was associated with a slower race completion time, compared to not

having a dermatological injury (Costa et al., 2016). Studies on injury-related MEs found that over a 7-day staged ultramarathon trail race, no association was found between female sex and MSK injuries or skin disorder, however, a decreased risk of the number of overall injuries was found with increasing age (Krabak et al., 2011). Overall, finishing time was not associated with a higher risk of the number of injuries (Krabak et al., 2011). During two iterations of a Western States Endurance Run (161km), the age and the sex of the participants were not found to affect the chance of having a ME (McGowan and Hoffman, 2015).

3.5.Challenges of medical care in trail running

During off-road running, hazardous obstacles, such as steep drops and uneven and destabilising ground (Dhawale and Venkadesan, 2023), increase the risk of tripping or falling. The technical and geographical element of trail running poses a real challenge for medical staff (Sollander et al., 2019). Trail runners injured or ill during an event often receive delayed medical care due to the logistical challenges of getting medical teams to remote areas on the trail route (Hoffman et al., 2014).

3.6.Gaps in literature

The following gaps in literature were identified: There is limited research on trail running in general but specifically on the African continent. Current literature has reported on trail running injuries, mostly including training and/or race-day injuries. Only nine studies globally have reported on injury-related MEs during trail events.

4. CONCLUSION

The most reported anatomical region of injury is the lower limb. The foot/toe was the most injured body area. The most reported injured tissue and pathology types involved the skin and blisters. There is a lack of literature on risk factors for male and specifically for female trail runners. Current literature on trail running injuries mainly observed participants over a longer period, including race and/or training-related injuries and many studies are on self-reported injuries. Limited trail studies only analyse injury-related MEs, and none involve the African continent.

Author contributions

1. Search and search strategy: Tyla Grobler

2. Composition of results and conclusion: Tyla Grobler
3. Review of results and article: Tyla Grobler, Carel Viljoen, Daniel Garnett and Christa Janse van Rensburg

Conflict of interest

The authors report no conflicting interest and declare no funding was received.

5. REFERENCES

Bahr, R., Clarsen, B., Derman, W., Dvorak, J., Emery, C. A., Finch, C. F., Hagglund, M., Junge, A., Kemp, S., Khan, K. M., Marshall, S. W., Meeuwisse, W., Mountjoy, M., Orchard, J. W., Pluim, B., Quarrie, K. L., Reider, B., Schwellnus, M., Soligard, T., Stokes, K. A., Timpka, T., Verhagen, E., Bindra, A., Budgett, R., Engebretsen, L., Erdener, U. & Chamari, K. 2020. International Olympic Committee Consensus Statement: Methods For Recording And Reporting Of Epidemiological Data On Injury And Illness In Sport 2020 (Including Strobe Extension For Sport Injury And Illness Surveillance (Strobe-Siis)). *British Journal of Sports Medicine,* 54**,** 372-389.

Buckler, D. G. & O'higgins, F. 2000. Medical Provision And Usage For The 1999 Everest Marathon. *British Journal of Sports Medicine,* 34**,** 205-9.

Center For Disease Control And Prevention. 2020. *Benefits of Physical Activity* [Online]. Cdc. Available: Https://Www.Cdc.Gov/Physicalactivity/Basics/Pa-Health/Index.Htm [Accessed 7 April 2022].

Costa, R. J. S., Snipe, R., Camões-Costa, V., Scheer, V. & Murray, A. 2016. The Impact Of Gastrointestinal Symptoms And Dermatological Injuries On Nutritional Intake And Hydration Status During Ultramarathon Events. *Sports Medicine - Open,* 2**,** 1-14.

Dawadi, S., Basyal, B. & Subedi, Y. 2020. Morbidity Among Athletes Presenting For Medical Care During 3 Iterations Of An Ultratrail Race In The Himalayas. *Wilderness & Environmental Medicine,* 31**,** 437-440.

Dhawale, N. & Venkadesan, M. 2023. How Human Runners Regulate Footsteps On Uneven Terrain. *Elife,* 12.

González-Lázaro, J., Arribas-Cubero, H. F. & Rodríguez-Marroyo, J. A. 2021. Muskuloskeletal Injuries In Mountain Running Races: A 5 Seasons Study. *Injury,* 52**,** 747-749.

Graham, S. M., Martindale, R. J. J., Mckinley, M., Connaboy, C., Andronikos, G. & Susmarski, A. 2021. The Examination Of Mental Toughness, Sleep, Mood And Injury Rates In An Arctic Ultra-Marathon. *European Journal of Sport Science,* 21**,** 100-106.

Graham, S. M., Mckinley, M., Chris, C. C., Westbury, T., Baker, J. S., Kilgore, L. & Florida-James, G. 2012. Injury Occurrence And Mood States During A Desert Ultramarathon. *Clinical Journal Of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine,* 22**,** 462-6.

Grewcock, L. 2019. *10 Reasons To Go Trail Running* [Online]. Redbull. Available: Https://Www.Redbull.Com/Za-En/Benefits-Of-Trail-Running [Accessed].

Harvard Health. 2021. *The Best Exercise For Your Bones* [Online]. Harvard Health Publishing. Available: Https://Www.Health.Harvard.Edu/Staying-Healthy/The-Best-Exercises-For-Your-Bones#:~:Text=When%20you%20land%20a%20jump,More%20as%20your%20speed%20increases. [Accessed].

Hespanhol Junior, L. C., Pillay, J. D., Van Mechelen, W. & Verhagen, E. 2015. Meta-Analyses Of The Effects Of Habitual Running On Indices Of Health In Physically Inactive Adults. *Sports Medicine,* 45**,** 1455-1468.

Hoffman, M. D., Pasternak, A., Rogers, I. R., Khodaee, M., Hill, J. C., Townes, D. A., Scheer, B. V., Krabak, B. J., Basset, P. & Lipman, G. S. 2014. Medical Services At Ultra-Endurance Foot Races In Remote Environments: Medical Issues And Consensus Guidelines. *Sports Medicine,* 44**,** 1055-1069.

Hoffman, M. D. & Stuempfle, K. J. 2015. Muscle Cramping During A 161-Km Ultramarathon: Comparison Of Characteristics Of Those With And Without Cramping. *Sports Medicine - Open,* 1**,** 1-9.

ITRA. 2020. *Discover Trail Running* [Online]. Available: Https://Itra.Run/About/Discovertrailrunning [Accessed].

Krabak, B. J., Waite, B. & Schiff, M. A. 2011. Study Of Injury And Illness Rates In Multiday Ultramarathon Runners. *Medicine and Science in Sports and Exercise,* 43**,** 2314-20.

Mailler, E. A. & Adams, B. B. 2004. The Wear And Tear Of 26.2: Dermatological Injuries Reported On Marathon Day. *British Journal of Sports Medicine,* 38**,** 498-501.

Mcgowan, V. & Hoffman, M. D. 2015. Characterization Of Medical Care At The 161-Km Western States Endurance Run. *Wilderness & Environmental Medicine,* 26**,** 29-35.

Medline Plus. 2017. *Benefits Of Exercise* [Online]. Nih. Available: Https://Medlineplus.Gov/Benefitsofexercise.Html#:~:Text=For%20older%20adults%2c%20research%20shows,Improve%20your%20sexual%20health. [Accessed].

Roy, B. A. 2015. Trail Running. *Acsm's Health & Fitness Journal,* 19**,** 3-4.

Scheer, B. V. & Murray, A. 2011. Al Andalus Ultra Trail: An Observation Of Medical Interventions During A 219-Km, 5-Day Ultramarathon Stage Race. *Clinical Journal Of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine,* 21**,** 444-6.

Scheer, B. V., Reljic, D., Murray, A. & Costa, R. J. S. 2014. The Enemy Of The Feet: Blisters In Ultraendurance Runners. *Journal of the American Podiatric Medical Association,* 104**,** 473-8.

Scheer, V., Basset, P., Giovanelli, N., Vernillo, G., Millet, G. P. & Costa, R. J. 2020. Defining Off-Road Running: A Position Statement From The Ultra Sports Science Foundation. *International Journal of Sports Medicine,* 41**,** 275-284.

Sollander, F., Porzi, J., Servant, G., Gojanovic, B. & Dussoix, P. 2019. [Trail Running: A Challenge For Medical Support Teams]. *Rev Med Suisse,* 15**,** 1370-1373.

Specter, F. 2017. *6 Benefits Of Trail Running* [Online]. Available: Https://Www.Runnersworld.Com/Uk/Training/Motivation/A775889/6-Benefits-Of-Trail-Running/ [Accessed 2 April 2020].

Vernillo, G., Savoldelli, A., La Torre, A., Skafidas, S., Bortolan, L. & Schena, F. 2016. Injury And Illness Rates During Ultratrail Running. *International Journal of Sports Medicine,* 37**,** 565-569.

Viljoen, C., Janse Van Rensburg, D. C. C., Van Mechelen, W., Verhagen, E., Silva, B., Scheer, V., Besomi, M., Gajardo-Burgos, R., Matos, S., Schoeman, M., Jansen Van Rensburg, A., Van Dyk, N., Scheepers, S. & Botha, T. 2022. Trail Running Injury Risk Factors: A Living Systematic Review. *British Journal of Sports Medicine,* 56**,** 577-587.

Viljoen, C. T., Janse Van Rensburg, D. C. C., Jansen Van Rensburg, A., Booysen, E., Chauke, S., Coetzee, P., Hurlimann, A., Jooste, M., Nibe, Y., Schulenburg, C., Korkie, E., Ramagole, D., Grant, C. & Cronje, T. 2021. One In Four Trail Running Race Entrants Sustained An Injury In The 12 Months Training Preceding The 2019 Skyrun Race. *Physical Therapy in Sport,* 47**,** 120-126.

Wengenmeir, M. 2021. *Everything You Need To Know About Trail Running* [Online]. Ispo. Available: Https://Www.Ispo.Com/En/News-Trends/Everything-You-Need-Know-About-Trail-Running [Accessed].

CHAPTER 3

Manuscript

Submitted to Sport Health
(Annexure A)

3 MANUSCRIPT

This manuscript chapter is presented in the format prescribed by the journal where it is submitted to, namely Sports Health. For this reason, the line spacing is 2.0, the tables are only presented at the end of the chapter and the referencing is done according to American Medical Association Manual of referencing style. At the time of submission, the manuscript had no identifying material but for cohesiveness of the present dissertation, this information has been added in.

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Injury-related medical encounters and associated risk factors during a high-altitude trail running event

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ABSTRACT

Background: Trail running races are often hosted in remote environments, challenging medical support. The sport is associated with a high incidence of injury and requires more work towards improved injury prevention in this field.

Aim: To determine the epidemiology and associated risk factors for injury-related medical encounters among trail runners participating in a high-altitude trail running event in 2019.

Hypothesis: Demographic variables (sex and age) are associated with a higher risk for injury-related medical encounters.

Study design: A descriptive cross-sectional study design.

Level of evidence: Level II

Methods: Medical staff documented all injury-related medical encounters among 412 trail runners during a high-altitude trail running event (100km, 65km, 38km). The study outcomes include injury prevalence (% of runners with medical encounters), clinical characteristics (anatomical region, body area, tissue type and pathology type) and risk factors associated with injury-related medical encounters ($p<0.05$).

Results: The overall injury-related medical encounter prevalence was 15.3%. The 100 km race accounted for most medical encounters (92.1%). Injuries mostly involved the lower limb (88.9%), specifically the foot (38.4%) and the knee (23.3%). The tissue type most affected was ligament/joint capsule (13.7%), followed by muscle/tendon (11%). Joint sprains (13.7%) and muscle strains (8.2%) were the pathology types most affected by injury. Sex and age categories did not show an associated risk of injury-related medical encounters during the races.

Conclusion: Approximately one in every six trail runners participating in a high-altitude trail event reported an injury-related medical encounter mostly affecting the lower limb. Sex and age showed no association with a higher risk of reporting an injury-related medical encounter.

Clinical relevance: Knowledge of the most common injury-related medical encounters could assist in the development of injury prevention strategies that can be incorporated into race preparation.

Keywords: trail running, trail races, trail injuries, off-road running, medical encounters

INTRODUCTION

Trail running is a mode of off-road running [15] which involves running in a natural environment over a variety of terrains (e.g. dirt road, forest trail, single track, beach sand, etc.), often including significant climbs and descents [14]. A trail race is defined as a race in a natural environment with a maximum of 20% paved roads [8].

Trail running is associated with health benefits such as improved cardiovascular stamina, core and leg muscle strength, balance, agility, and mental well-being [16]. Although trail running has health benefits, it still involves a high risk of injury [18].

The overall prevalence of injuries in trail running is reported as high as 90% [18]. The lower limb is the most reported injured anatomical region, with the foot/toe being the most reported body area of injury [18]. The tissue type most reported is superficial tissue/skin with joint sprains, followed by tendinopathies as the most reported pathology type of injury [18]. In rare cases, fatal injuries have been reported in trail running [12]. Considering the challenges of providing medical care (finding and evacuating runners) at trail running events hosted in remote regions [7] there is a need to understand the nature of medical encounters (MEs) reported at these events.

In trail running literature, only eight studies globally reported on injury-related MEs [2-6,9,10,13,17]. Most of these studies reported blisters as the most common injury-related ME [2,6,9,13]. One study found that musculoskeletal (MSK) injuries accounted for 32.8% of all MEs, and skin-related disorders accounted for 16.9%. Ankle sprain (28.6%) and plantar fasciitis (28.6%) were the most common MSK injuries, and foot blisters (53.8%) were the most common skin-related disorders [17]. Similarly, the most common injury-related ME during three iterations of an ultra-trail race in the Himalayas was ankle sprain [5].

Three previous studies reported injury among trail runners in Africa [19-21], but no study specifically reported injury-related MEs in the African context. There is a need to understand which injuries require medical care to improve medical planning before trail running events hosted in remote regions.

This study aims to determine the epidemiology and associated risk factors for injury-related MEs among trail runners that participated in a high-altitude trail running event in South Africa in 2019.

METHODS

Study design

In this study, a descriptive, cross-sectional study design was conducted to investigate a dataset collected during a high-altitude trail running event.

Participants and data collection

The data were collected under the larger study titled: Reducing Injury and Illness at Adventure Sports Events: A 10-Year Longitudinal Study (2018-2028) (REC: 460/2018). Further ethical approval was obtained from the Research Ethics Committee of the University of Pretoria (REC: 582/2022) (Annexure B) to analyse the data.

The participants of this study included all trail runners (n=412) who participated in any of the 2019 high-altitude trail running event distances (38 km, 65 km, 100 km). During the race, all MEs were recorded by the race-day medical staff (Annexure C). For the purpose of this study, only the injury-related ME data was investigated. An injury-related ME was defined as: any injury reported to medical staff during the race, by a trail runner participating in these 2019

high-altitude trail running events. Demographic data of all race starters were publicly available on the race's website. A letter of permission to access the clinical records was obtained (Annexure D).

Race characteristics

The data analysed in this study was collected in 2019 during a high-altitude trail event. The event was hosted in a remote mountainous region in South Africa and consisted of three race categories: 100 km, 65 km, and 38 km. The vertical gain for the 100 km race was 4445 m, for the 65 km race 3145 m, and for the 38 km race 2100 m. The races consisted mainly of self-navigation and trail runners were semi self-sufficient in carrying their own nutrition and hydration between aid stations. All race categories were run at an average altitude of >2200 m.

Outcome measures

The primary outcome measures of this study are 1) period prevalence of injury-related MEs (% of trail runners that reported an injury-related ME during the race), 2) frequency (n, %) of injury reported by anatomical region, body area, tissue, and pathology type, and 3) risk factors associated with injury ($p<0.05$). In this study, we reported outcomes in-line with the 2020 International Olympic Committee (IOC) consensus statement on methods for recording and reporting of epidemiological data on injury and illness in sport [1].

Statistical analysis

All the recorded data on injury-related MEs were collected and extracted from the clinical records into an Excel spreadsheet for analysis. The data was analysed in R.[11] The data analysis consisted of descriptive statistics such as frequencies and proportions. The prevalence of injury-related MEs was determined by taking the number of injury-related MEs and dividing it by the number of participants who started the races. The frequency of injury-related MEs

was given as a number and percentage of all participants. Clinical characteristics (anatomical region, body area, tissue and pathology type) were reported as proportions of MEs. For the risk factor association, a frequency table (2 by 2) was used and the significance was determined according to Chi-square statistics. All statistical tests were performed at a 5% level of significance.

RESULTS

Characteristics of race starters

A total of 412 participants started the races that formed part of a high-altitude trail running event. Most race starters were male (72.6%, n=299) and in the open age category (49.5%, 21-39 years). The majority of the participants competed in the 100 km race. The demographic characteristics of all the race starters are shown in Table 1. The age category data for the 38 km race starters were not publicly available.

INSERT TABLE 1 HERE

Injury-related ME prevalence

Among the 412 race starters, 188 MEs were reported. In total, 63 trail runners reported an injury-related ME, indicating an overall injury prevalence of 15.3%. Table 2 depicts the number of injured race starters and injury-related ME prevalence by race distance and sex categories.

INSERT TABLE 2 HERE

In the 100 km race 92.1% injury-related MEs were reported, 6.3% in the 65 km race and none in the 38 km race. Male race starters reported most of the injury-related MEs (82.5%).

Clinical characteristics of injury-related MEs

During the races, 53 race starters reported one injury and 10 reported two, with a total injury count of 73. The frequency of all injury-related MEs (n, %) by anatomical region and body area are presented in Table 3. Due to the low number of injury-related MEs reported in the 65 km and 38 km races, only the injury frequencies for all injuries are presented.

INSERT TABLE 3 HERE

Most of the injuries occurred in the lower limb (88.9%), with the foot (38.4%) and knee (23.3%) mainly involved. The frequency of injured tissue and pathology types are shown in Table 4.

INSERT TABLE 4 HERE

Race medical staff did not report all data relating to injured tissue and pathology types. From the data collected, the tissue type most affected was ligament/joint capsule (13.7%), followed by muscle/tendon (11%). The most affected pathology type was joint sprain (13.7%) followed by muscle strain (8.2%).

Of the 412 participants, 52 (12.6%) reported blisters. During this specific race, medical staff routinely tested runners' blood pressures and enquired about blisters at medical aid stations. However, it is unclear from the clinical records whether the recorded blisters were actual MEs

or skin-related injuries reported as part of the routine enquiry by medical staff, i.e. blisters not needing actual medical attention. For that reason, blisters were not included as an injury-related ME in this study but were reported in isolation as it is one of the highest reported pathologies at this stage.[18] (Table 5)

INSERT TABLE 5 HERE

Due to the low number of injuries reported in the 65 km and 38 km race distance categories, the risk factor analysis only considered injury-related MEs reported in the 100 km race (n=243). Sex and age category as risk factors for injury-related MEs is presented in Table 6.

INSERT TABLE 6 HERE

Neither sex (p=0.0605) nor age (p=0.7771) showed a significant association with injury-related ME.

DISCUSSION

This study investigated the epidemiology and the associated risk factors of injury-related MEs in race starters of a high-altitude trail running event. The main findings include: 1) 15.3% of participants reported an injury to the medical staff on the day of the races, 2) the lower limb was the most affected anatomical region (88.9%), 3) the foot and knee were the most commonly affected body area (38.4% and 23.3% respectively), 4) the most commonly affected tissue type was ligament/joint capsule (13.7%) followed by muscle/tendon (11%), 5) the pathology type most reported was joint sprains (13.7%) followed by muscle strain (8.2%), 6) sex and age were not significant risk factors for an injury-related ME.

Prevalence of injury-related medical encounters

The prevalence of injury-related MEs during a 2019 high-altitude trail running event was 15.3%. A systematic review of current literature on trail running injuries found the injury prevalence range between 1.3% and 90%.[18] Only three studies related to MEs, reported the prevalence of injury.[5,6,13] During the seven-stage Manaslu Trail race in 2014, 2015 and 2016 the total prevalence for injury-related MEs was 38%.[5] Over the three years, the injury prevalence for MSK (sprain/strain) MEs was 18%, for abrasions/lacerations 12%, and for blisters 8% [5]. In total, 85% of racers sustained an injury during a three-day Arctic ultramarathon [6] In a five-day ultramarathon stage trail race, 56.5% of competitors suffered a MEs [13]. These three studies on MEs report a higher injury prevalence than the current study. The reason could be that the distances for all studies were significantly further than the 2019 high-altitude races (100 km, 65 km and 38 km). The Manaslu Trial covered 212 km [5], the Arctic Ultramarathon 193km [6] and the Al Andalus Ultra Trail 219 km [13].

Clinical characteristics of injury-related medical encounters

The anatomical region affected mainly by injury during the 2019 high-altitude races was the lower limb (88.9%). A current systematic review reports that in trail running literature, the lower limb is the most common anatomical region of injury in 83.3% of studies [18]. Only one other study reported a percentage for anatomical region of injury. This study found that 92.6% of skin and MSK MEs involved the lower limb [9].

The foot followed by the knee was the most affected body area in this study (38.4% and 23.3% respectively). Literature reports different areas, although the foot and knee are in the top three in most of the studies [4,9,13,17]. A recent review identified that the most common injured body area is the toe/foot (55,6%) followed by the ankle (50.0%) and the hip/groin (50.0%) [18].

Specifically for race day MEs, the majority of skin and MSK injuries occurred in the foot (73.7%) followed by the lower leg (8.6%) and ankle (4.9%) [9]. Nine out of 22 (40.9%) MSK injuries were knee injuries in a five day ultramarathon stage race [13].

The most affected tissue type in this study was ligament/joint capsule (13.7%). A recent systematic review of all trail running injuries found that superficial/skin injuries were reported in 72.2% of studies, muscle/tendon injuries were reported in 44.4% of studies and ligament/joint capsule injuries in 38.9% of studies [18]. Out of 20 MSK injuries over two years in a 161km Western States Endurance Run, seven (35%) MEs resulted from a sprain, strain or tendinitis [10].

Joint sprain was the most common pathology type (13.7%) followed by muscle strain (8.2%). A recent systematic review found that specific injuries mostly included blisters (50%) followed by joint sprains (44.4%) and tendinopathies (38.9%) [18]. Similarly to the current study, ankle sprain was the most common MSK injury in an ultratrail race in the Himalayas [5]. During the Vigolana Trail (65km), the most common MSK injuries were ankle sprain (28.6%) and plantar fasciitis (28.6%), and the most common dermatological injury was foot blisters (52.8%).[17] In a seven day staged 240km ultramarathon, tendonitis was the most common MSK injury.[9] During a five day ultramarathon stage race (Al Andalus Ultra Trail), nine out of 22 (40.9%) MSK MEs were for patellofemoral pain, followed by ankle inversion injuries (22.7%).[13] However, blisters were the most common ME, accounting for 33 out of 99 (33.3%) of the total MEs. In an Arctic ultramarathon, out of 12 participants, two (16.7%) reported hip MSK pain, and approximately two-thirds were treated for abrasions and/or blisters.[6] The current study did not include blisters as part of the injury-related MEs as the clinical records did not provide detail on whether the recorded blisters were actual MEs or instead reported as part of the routine

enquiry by medical staff, i.e., not requiring actual medical attention., although of the participants who had an injury-related ME, 21.3% also had blisters.

Risk factors for injury-related medical encounters

Sex and age category did not account for risk factors for injury-related MEs. Similarly, in a recent systematic review, authors found consistent evidence that sex and age are not risk factors for injury.[18] Likewise no association with sex and MSK or skin injuries is seen in a staged ultramarathon, but increasing age decreased the risk of overall MSK and skin injuries.[9] During a Western States endurance run (161km) over two years (2012 and 2013), age and sex did not affect the chance of a competitor having a ME.[10] A study conducted over a 7 day stage race of 240km found that overall finishing time was not associated with higher risk of number of injuries.[9] The current study had many trail runners that did not finish (DNF). Therefore, race finishing time was not included in the risk factor analysis.

Recommendations

From these findings, training programs are recommended to focus on lower limb strengthening, specifically of the foot and knee. Recommendations for future studies on injury-related MEs should document injuries according to the IOC consensus statement on injury definitions to ensure uniformity. The medical staff collecting data should be aware of the different types of injuries relating to tissue and pathology type and accurately document them. Future studies should focus more on intrinsic risk factors for injury, including height, weight and finishing time.

Limitations

The medical staff collecting the data did not capture all relevant data. There was a lot of unspecified data relating to the injuries, specifically tissue and pathology type. Many participants sustaining an ME had not specified whether it was an injury or illness-related ME. These unspecified MEs were not included in the analysis. Only MEs detailing further information on the anatomical region, body area, tissue and pathology type were included. Most details on the tissue and pathology types were not included in the clinical records. Further, injuries were only recorded if reported as an ME. Therefore, some participants could choose not to report injuries to the medical staff or could have underreported injuries.

CONCLUSION

Approximately one in every six trail runners participating in a high-altitude trail event reported an injury-related ME, mainly affecting the lower limb. Sex and age have no association with a higher risk of reporting an injury-related ME. Improved knowledge of the basic epidemiology and associated injury risk factors could aid in designing improved injury prevention strategies for runners participating in high-altitude trail running races.

Table 1: Demographics (sex, age categories, and race distance) of the trail runners starting the high-altitude race in 2019

Characteristics		All participants (n=412)	100 km (n=243)	65 km (n=121)	38 km (n=48)
Sex n (%)	Males	299 (72.6)	190 (78.2)	84 (69.4)	25 (52.1)
	Females	113 (27.4)	53 (21.8)	37 (30.6)	23 (47.9)
Age categories n (%)	Open (21-39 years)	-	128 (52.7)	76 (62.8)	-
	Vets (40-49 years)	-	97 (39.9)	28 (23.1)	-
	Masters (50+ years)	-	18 (7.4)	17 (14.0)	-

Table 2: Prevalence of injury-related medical encounters by race distance and sex categories

Characteristic		Number of injured race starters (n=63)	Injury prevalence (% of injured race starters per category)
Race distance category	100 km (n=243)	58	23.9
	65 km (n=121)	4	3.3
	38 km (n=48)	-	-
	Missing	1	-
Sex	Male (n=299)	52	17.4
	Female (n=113)	9	8.0
	Missing	2	-

Table 3: Anatomical region and body area data of the injury-related MEs

Anatomical region	Body area	All injuries (n=73) n (%)
Upper Limb	**All**	**2 (2.8)**
	Shoulder	1 (1.4)
	Hand	1 (1.4)
Trunk	**All**	**5 (6.9)**
	Thoracic spine	1 (1.4)
	Lumbosacral	4 (5.5)
Lower Limb	**All**	**65 (88.9)**
	Hip/groin	6 (8.2)
	Thigh	2 (2.7)
	Knee	17 (23.3)
	Ankle	8 (11.0)
	Foot	28 (38.4)

Anatomical region	Body area	All injuries (n=73) n (%)
	Unspecified	4 (5.5)
Unspecified	**All**	**1 (1.4)**
	Region unspecified	1 (1.4)

Table 4: Tissue and pathology type of the injury-related MEs

Tissue type	Pathology type	All injuries (n=73) n (%)
Muscle/Tendon	**All**	**8 (11.0)**
	Muscle injury	6 (8.2)
	Tendinopathy	2 (2.7)
Bone	**All**	**1 (1.4)**
	Fracture	1 (1.4)
Ligament/Joint capsule	**All**	**10 (13.7)**
	Joint sprain	10 (13.7)
Superficial tissues/skin	**All**	**4 (5.6)**
	Abrasion	3 (4.1)
	Chaffing	1 (1.4)
Unspecified	**All**	**50 (68.5)**

Table 5: Blisters

Blisters	n (%)
Yes	52 (12.6)
No	112 (27.2)
Missing value	248 (60.2)

Table 6: Risk factors relating to injury-related MEs in the 100 km race distance

Possible risk factor		All 100km participants (n=243)	Medical encounter	p-value
Sex	Male	190 (78.2)	51 (87.9)	p=0.0605
	Female	53 (21.8)	7 (12.1)	
Age Category	Vets	97 (39.9)	21 (36.2)	p=0.7771
	Open	128 (52.7)	32 (55.2)	
	Masters	18 (7.4)	5 (8.6)	

REFERENCES

1. Bahr R, Clarsen B, Derman W, et al. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). *British Journal of Sports Medicine.* Apr 2020;54(7):372-389. doi:10.1136/bjsports-2019-101969

2. Buckler DG, O'Higgins F. Medical provision and usage for the 1999 Everest marathon. *British Journal of Sports Medicine*. 2000;34(3):205-9.

3. Costa R, Snipe R, Camões-Costa V, Scheer V, Murray A. The impact of gastrointestinal symptoms and dermatological injuries on nutritional intake and hydration status during ultramarathon events. *Sports Medicine Open*. 2016;2(1):1-14. doi:10.1186/s40798-015-0041-9

4. Damoisy J-B, Destombes V, Savina Y, Pröpper CJ, Braun C, Tanné C. Epidemiology, prevention methods, and risk factors of foot blisters in French trail ultramarathons. *The Journal of Sports Medicine and Physical Fitness*. 2023;

5. Dawadi S, Basyal B, Subedi Y. Morbidity Among Athletes Presenting for Medical Care During 3 Iterations of an Ultratrail Race in the Himalayas. *Wilderness & environmental medicine*. 2020;31(4):437-440. doi:10.1016/j.wem.2020.08.001

6. Graham SM, Martindale RJJ, McKinley M, Connaboy C, Andronikos G, Susmarski A. The examination of mental toughness, sleep, mood and injury rates in an Arctic ultra-marathon. *European Journal of Sport Science*. 2021;21(1):100-106. doi:10.1080/17461391.2020.1733670

7. Hoffman MD, Stuempfle KJ. Muscle Cramping During a 161-km Ultramarathon: Comparison of Characteristics of Those With and Without Cramping. *Sports Medicine - Open*. 2015;1(1):1-9. doi:10.1186/s40798-015-0019-7

8. ITRA. Discover Trail Running 2 April, 2020. https://itra.run/About/DiscoverTrailRunning

9. Krabak BJ, Waite B, Schiff MA. Study of injury and illness rates in multiday ultramarathon runners. *Medicine and Science in Sports and Exercise*. Dec 2011;43(12):2314-20. doi:10.1249/MSS.0b013e318221bfe3

10. McGowan V, Hoffman MD. Characterization of medical care at the 161-km Western States Endurance Run. *Wilderness & Environmental Medicine*. 2015;26(1):29-35. doi:10.1016/j.wem.2014.06.015

11. R Core Team. The R Project for Statistical Computering. The R Foundation. https://www.r-project.org

12. Roi GS. Fatal Events Related to Running Competitions in the Mountains. *Wilderness & Environmental Medicine*. 2021/06/01/ 2021;32(2):176-180. doi:https://doi.org/10.1016/j.wem.2020.12.001

13. Scheer BV, Murray A. Al Andalus Ultra Trail: an observation of medical interventions during a 219-km, 5-day ultramarathon stage race. *Clinical Journal of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine*. 2011;21(5):444-6. doi:10.1097/JSM.0b013e318225b0df

14. Scheer V, Basset P, Giovanelli N, Vernillo G, Millet GP, Costa RJ. Defining off-road running: a position statement from the ultra sports science foundation. *International Journal of Sports Medicine*. 2020;41(05):275-284.

15. Scheer V, Basset P, Giovanelli N, Vernillo G, Millet GP, Costa RJS. Defining off-road running: a position statement from the ultra sports science foundation. *International Journal of Spoorts Medicine*. 2020;doi:10.1055/a-1096-0980

16. Specter F. 6 benefits of trail running. Accessed 2 April, 2020. https://www.runnersworld.com/uk/training/motivation/a775889/6-benefits-of-trail-running/

17. Vernillo G, Savoldelli A, La Torre A, Skafidas S, Bortolan L, Schena F. Injury and Illness Rates During Ultratrail Running. *International Journal of Sports Medicine*. 2016;37(7):565-569. doi:10.1055/s-0035-1569347

18. Viljoen C, Janse van Rensburg DCC, van Mechelen W, et al. Trail running injury risk factors: a living systematic review. *British Journal of Sports Medicine* May 2022;56(10):577-587. doi:10.1136/bjsports-2021-104858

19. Viljoen CT, Janse van Rensburg DC, Jansen van Rensburg A, et al. One in four trail running race entrants sustained an injury in the 12 months training preceding the 2019 SkyRun race. *Physical Therapy in Sport*. 2021/01/01/ 2021;47:120-126. doi:https://doi.org/10.1016/j.ptsp.2020.11.029

20. Viljoen CT, Janse van Rensburg DC, Verhagen E, van Mechelen W, Korkie E, Botha T. Epidemiology, Clinical Characteristics, and Risk Factors for Running-Related Injuries among South African Trail Runners. *International Journal of Environmental Research and Public Health*. 2021;18(23):12620.

21. Viljoen CT, Sewry N, Schwellnus MP, Janse van Rensburg DC, Swanevelder S, Jordaan E. Independent Risk Factors Predicting Gradual Onset Injury in 2824 Trail Running Race Entrants: SAFER XVIII Study. *Wilderness & Environmental Medicine*. 2021/07/12/ 2021;doi:https://doi.org/10.1016/j.wem.2021.04.002

CHAPTER 4

Discussion

4 INTRODUCTION

This chapter aims to discuss the present study's results and compare them to current literature in the field. Recommendations and limitations of the study also form part of the discussion.

4.1 DISCUSSION

Only a few studies investigated medical encounters (MEs) during trail running races. The purpose of this study was to only look at the injury-related MEs in a high altitude race (>2200 m), with a substantial amount of vertical gain, hosted in a specific South African environment. Medical staff recorded the MEs in this study at the 2019 SkyRun Races. Outcomes reported included the prevalence of injury (% of runners reporting a ME), clinical characteristics (anatomical region, body area, tissue and pathology type), and the associated risk factors for injury.

To the authors knowledge, there are only eight studies published on injury-related MEs in trail running (Buckler and O'Higgins, 2000, Dawadi et al., 2020, Graham et al., 2021, Krabak et al., 2011, McGowan and Hoffman, 2015, Hoffman and Stuempfle, 2015, Scheer and Murray, 2011, Vernillo et al., 2016). Many of these studies focussed on stage races over multiple days (Dawadi et al., 2020, Graham et al., 2012, Scheer and Murray, 2011, Krabak et al., 2011, Scheer et al., 2014). Some studies merely indicated that there were musculoskeletal (MSK) injuries but did not detail the clinical characteristics of the reported injuries (Buckler and O'Higgins, 2000, Dawadi et al., 2020). One study only investigated certain injuries, such as dermatological injuries (Costa et al., 2016).The present study is novel as all injury-related MEs were recorded according to the International Olympic Committee (IOC) guidelines (Bahr et al., 2020), and it is the only study conducted on injury-related MEs on the African continent.

The primary findings of this study are that the injury prevalence during a high-altitude trail race, namely the 2019 SkyRun was 15.3%, implying that 15.3% of the participants who started one of the races reported an injury to the medical staff during the race. Most of the injuries occurred in the lower limb (88.9%), specifically the foot, followed by the knee and then the ankle (38.4%, 23.3% and 11%, respectively). The tissue type most commonly affected was ligament/joint capsule (13.7%), followed by muscle/tendon (8.2%), and the pathology type most commonly reported included joint sprain (13.7%), followed by muscle strain (8.2%). Most of the injuries occurred in the 100 km race (92.1%), four in the 65 km race, and one in a

race distance not documented. Due to most of the injuries occurring in the 100 km race, the risk factor analysis only included the participants who started the 100 km race. The present study considered two possible risk factors, sex and age category, which were not significantly associated with reported injury-related MEs.

Three studies on MEs investigated the prevalence of injury-related MEs and reported the prevalence as 38%, 85% and 56.5% respectively (Dawadi et al., 2020, Graham et al., 2021, Scheer and Murray, 2011). These values are all higher than the present study which found the prevalence of injury-related MEs to be 15.3%. This could be because the other three events were all multi-day stage events and covered a much greater distance than the study at hand. More extreme terrain and weather conditions are usually encountered by multi-day trail runners who also usually carry heavy packs with food, water and trail running gear, these factors may influence the prevalence of injury (Vernillo et al., 2016). Skin-related injuries were also included in the above-mentioned studies whereas blisters were excluded in this study.

Most of the studies did not report on the clinical characteristics of injury, but mainly named the most affected pathology type. The other elements (tissue type, body area and anatomical region) can be determined from the pathology types. In the study at hand, 88.9% of injury-related MEs occurred in the lower limb, similar to RacingThePlanet ultramarathon, which found 92.6% of injury-related MEs in the lower limb (Krabak et al., 2011). During trail running, mainly the lower limbs are placed under stress during the running motion, which could explain the lower limb as being the most common site of injury. In this study, the foot, followed by the knee and then the ankle, were the most affected body area of injury (38.4%, 23.3% and 11%, respectively). Similarly, the foot, followed by the lower leg, ankle and knee, were the most common injured body area of injury during RacingThePlanet ultramarathon (73.7%, 8.6%, 4.9% and 3.5%, respectively) (Krabak et al., 2011). During the Al Andalas Ultra Trail the knee was the most affected MSK injury (40.9%) (Scheer and Murray, 2011). The present study found the pathology type most commonly affected by injury to be joint sprains (13.7%) followed by muscle strains (8.2%). During the Vigolana Trail Race (65 km), plantar fasciitis and ankle sprains were the most common MSK injuries, and foot blisters were the most common dermatological injury (52.8%) (Vernillo et al., 2016). During a seven-day stage race of 240 km, tendonitis was the most common MSK injury (Krabak et al., 2011). During a five-day ultramarathon stage race, patellofemoral pain accounted for nine out of 22 (40.9%) MSK MEs, followed by 22.7% for ankle inversion injuries, although blisters accounted for 33.3% of

the total MEs and therefore were the most common injury-related ME (Scheer and Murray, 2011). Approximately two-thirds of the participants were treated for blisters and/or abrasions during an Arctic ultramarathon, and two out of 12 participants (16.7%) reported hip MSK pain (Graham et al., 2021). The reason for joint sprains being quite common in literature could be due to the fact that trail running is synonymous for variations of uneven surfaces (Viljoen et al., 2022). Most of these studies found blisters to account for most injury-related MEs which is supported by the foot being the most common body area of injury in most studies. This could be due to the participants' mileage (ultramarathons) that spanned over multiple days. This study did not report on blisters as a ME.

There is consistent evidence, including the present study, that found age and sex not to be associated with an increased risk of injury during trail races (Krabak et al., 2011, McGowan and Hoffman, 2015).

The study at hand aimed to identify other risk factors such as height, weight and finishing time. According to the conditions of the waiver of consent, the data needed to be completely de-identified and no additional identifiable data could be obtained from the race organiser. As the height and weight of each participant were not recorded as part of the medical records on race day, it could not be included in this study. Due to the high number of participants who did not finish (DNF), it was not valuable to include race finishing time in the risk factor calculation. Participants who DNF, possibly because of injury, would not have crossed the finish line or received a finishing time. This would, therefore, give an inaccurate comparison on whether race finishing time impacted injury. It would furthermore not have been possible to link the publicly available race finish times with the de-identified participant data. Krabak et al. (2011) found no association between overall finishing time and suffering a ME.

4.2 RECOMMENDATIONS

4.2.1 Clinical recommendations

Trail runners require education on the most common injuries during high altitude and increased elevation trail races to work towards preventing and managing these injuries during races. Understanding the most common injuries, physiotherapists can educate runners on self-taping techniques on race-day, and blister management. Leading up to the race, trail running training programs should focus on lower limb strengthening, specifically for high altitude and increased elevation trail races. This part of the body is placed under the most stress during trail running

and is the anatomical region most injured during trail races. In the present study, joint sprains were the most common pathology type of injury. These injuries could render athletes unable to self-ambulate. Therefore, medical teams should be prepared, and have experience working in remote areas. Trail runners participating in trail races in remote areas should also consider doing first aid training, as medical teams often have challenges getting to remote areas on the route (Hoffman et al., 2014).

4.2.2 Research recommendations

Future injury-related ME studies should be documented according to the IOC consensus statement on recording and reporting injuries (Bahr et al., 2020) to ensure uniformity in documenting injuries throughout different studies. More diverse data capturing at races will allow more risk factor analyses. Data should be collected at various races as this study only looked at a specific race. Future studies should focus on female trail runners over various distances, as the majority of the participants in the present study competed in the 100km race and were male. Injuries among short distance trail runners are largely neglected and future research should target these distances where mostly inexperienced trail runners participate in. Injuries in the African and specifically the South African context have not previously been investigated. The researcher recommends future studies investigate how the various local environments in combination with the South African mentality towards ultra-endurance running affects the injury profile and associated risk for injury.

4.3 LIMITATIONS

The medical staff who collected the data did not capture all relevant data possible, specifically for tissue and pathology type of injury, of which 68.5% of this data was unspecified. The medical staff collected data on both injury and illness-related MEs, although they did not always document whether the encounter was for an injury or an illness. Therefore, not all ME data could be included. Only injury-related MEs that detailed further information, such as anatomical region or body area, could be analysed. If this information was missing, we excluded the participant as we could not confirm whether it was an injury or illness-related encounter. Blisters should also form part of MEs, but it was not documented whether it was a ME or just information collected during the race by relevant stakeholders. The findings of the study at hand are limited to the specific geographical location of the SkyRun, specifically high altitude with great elevation and therefore cannot be generalised to all trail races.

4.4 CONCLUSION

The present study identified that the injury prevalence in a high-altitude race was 15.3% and that most of the injuries in this race occurred in the lower limb (88.9%), specifically the foot (38.4%), followed by the knee (23.3%) and then the ankle (11%). Most of these injuries were joint sprains (13.7%), followed by muscle strains (8.2%). Sex and age category were not found to be risk factors in the present study. The findings of this study are important for the relevant stakeholders to medically prepare for a race to manage the injuries during a race. Physiotherapists could use the present study's findings to also guide risk management strategies unique to the specific geographical location of this race.

4.5 REFERENCES

Bahr, R., Clarsen, B., Derman, W., Dvorak, J., Emery, C. A., Finch, C. F., Hagglund, M., Junge, A., Kemp, S., Khan, K. M., Marshall, S. W., Meeuwisse, W., Mountjoy, M., Orchard, J. W., Pluim, B., Quarrie, K. L., Reider, B., Schwellnus, M., Soligard, T., Stokes, K. A., Timpka, T., Verhagen, E., Bindra, A., Budgett, R., Engebretsen, L., Erdener, U. & Chamari, K. 2020. International Olympic Committee Consensus Statement: Methods For Recording And Reporting Of Epidemiological Data On Injury And Illness In Sport 2020 (Including Strobe Extension For Sport Injury And Illness Surveillance (Strobe-Siis)). *British Journal of Sports Medicine,* 54**,** 372-389.

Buckler, D. G. & O'higgins, F. 2000. Medical Provision And Usage For The 1999 Everest Marathon. *British Journal of Sports Medicine,* 34**,** 205-9.

Costa, R. J. S., Snipe, R., Camões-Costa, V., Scheer, V. & Murray, A. 2016. The Impact Of Gastrointestinal Symptoms And Dermatological Injuries On Nutritional Intake And Hydration Status During Ultramarathon Events. *Sports Medicine - Open,* 2**,** 1-14.

Dawadi, S., Basyal, B. & Subedi, Y. 2020. Morbidity Among Athletes Presenting For Medical Care During 3 Iterations Of An Ultratrail Race In The Himalayas. *Wilderness & Environmental Medicine,* 31**,** 437-440.

Graham, S. M., Martindale, R. J. J., Mckinley, M., Connaboy, C., Andronikos, G. & Susmarski, A. 2021. The Examination Of Mental Toughness, Sleep, Mood And Injury Rates In An Arctic Ultra-Marathon. *European Journal of Sport Science,* 21**,** 100-106.

Graham, S. M., Mckinley, M., Chris, C. C., Westbury, T., Baker, J. S., Kilgore, L. & Florida-James, G. 2012. Injury Occurrence And Mood States During A Desert Ultramarathon. *Clinical Journal of Sport Medicine : Official Journal of The Canadian Academy of Sport Medicine,* 22**,** 462-6.

Hoffman, M. D., Pasternak, A., Rogers, I. R., Khodaee, M., Hill, J. C., Townes, D. A., Scheer, B. V., Krabak, B. J., Basset, P. & Lipman, G. S. 2014. Medical Services At Ultra-Endurance Foot Races In Remote Environments: Medical Issues And Consensus Guidelines. *Sports Medicine,* 44**,** 1055-1069.

Hoffman, M. D. & Stuempfle, K. J. 2015. Muscle Cramping During A 161-Km Ultramarathon: Comparison Of Characteristics Of Those With And Without Cramping. *Sports Medicine - Open,* 1**,** 1-9.

Krabak, B. J., Waite, B. & Schiff, M. A. 2011. Study Of Injury And Illness Rates In Multiday Ultramarathon Runners. *Medicine and Science in Sports and Exercise,* 43**,** 2314-20.

Mcgowan, V. & Hoffman, M. D. 2015. Characterization Of Medical Care At The 161-Km Western States Endurance Run. *Wilderness & Environmental Medicine,* 26**,** 29-35.

Scheer, B. V. & Murray, A. 2011. Al Andalus Ultra Trail: An Observation Of Medical Interventions During A 219-Km, 5-Day Ultramarathon Stage Race. *Clinical Journal Of Sport Medicine : Official Journal of the Canadian Academy of Sport Medicine,* 21**,** 444-6.

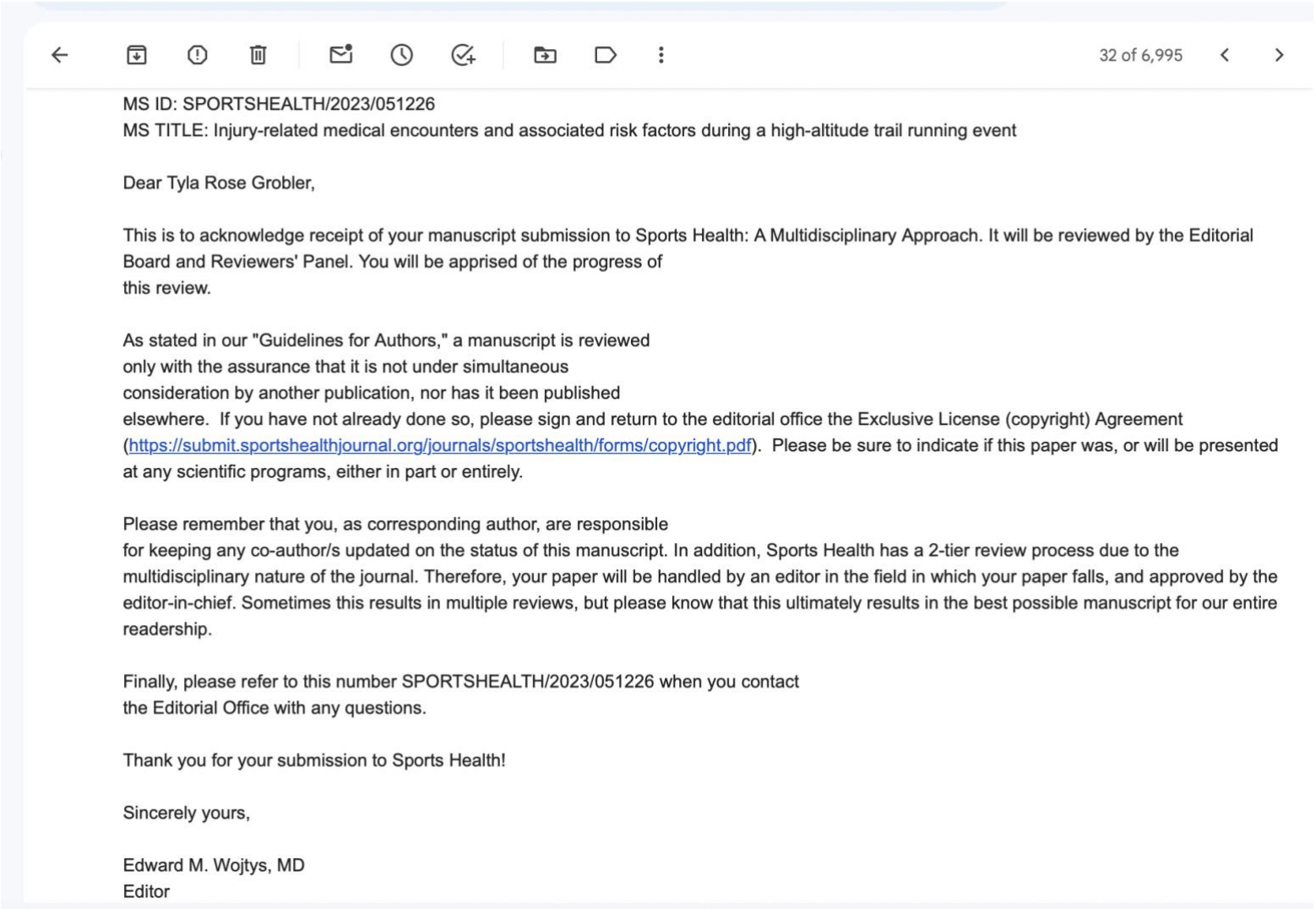
Scheer, B. V., Reljic, D., Murray, A. & Costa, R. J. S. 2014. The Enemy Of The Feet: Blisters In Ultraendurance Runners. *Journal of The American Podiatric Medical Association,* 104**,** 473-8.

Vernillo, G., Savoldelli, A., La Torre, A., Skafidas, S., Bortolan, L. & Schena, F. 2016. Injury And Illness Rates During Ultratrail Running. *International Journal of Sports Medicine,* 37**,** 565-569.

Viljoen, C., Janse Van Rensburg, D. C. C., Van Mechelen, W., Verhagen, E., Silva, B., Scheer, V., Besomi, M., Gajardo-Burgos, R., Matos, S., Schoeman, M., Jansen Van Rensburg, A., Van Dyk, N., Scheepers, S. & Botha, T. 2022. Trail Running Injury Risk Factors: A Living Systematic Review. *British Journal of Sports Medicine,* 56**,** 577-587.

ANNEXURES

ANNEXURE A: Proof of submission to journal



32 of 6,995

MS ID: SPORTSHEALTH/2023/051226
MS TITLE: Injury-related medical encounters and associated risk factors during a high-altitude trail running event

Dear Tyla Rose Grobler,

This is to acknowledge receipt of your manuscript submission to Sports Health: A Multidisciplinary Approach. It will be reviewed by the Editorial Board and Reviewers' Panel. You will be apprised of the progress of this review.

As stated in our "Guidelines for Authors," a manuscript is reviewed only with the assurance that it is not under simultaneous consideration by another publication, nor has it been published elsewhere. If you have not already done so, please sign and return to the editorial office the Exclusive License (copyright) Agreement (https://submit.sportshealthjournal.org/journals/sportshealth/forms/copyright.pdf). Please be sure to indicate if this paper was, or will be presented at any scientific programs, either in part or entirely.

Please remember that you, as corresponding author, are responsible for keeping any co-author/s updated on the status of this manuscript. In addition, Sports Health has a 2-tier review process due to the multidisciplinary nature of the journal. Therefore, your paper will be handled by an editor in the field in which your paper falls, and approved by the editor-in-chief. Sometimes this results in multiple reviews, but please know that this ultimately results in the best possible manuscript for our entire readership.

Finally, please refer to this number SPORTSHEALTH/2023/051226 when you contact the Editorial Office with any questions.

Thank you for your submission to Sports Health!

Sincerely yours,

Edward M. Wojtys, MD
Editor

ANNEXURE B: Ethics approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 18 March 2022 and Expires 18 March 2027.
- IORG #: IORG0001762 OMB No. 0990-0279 Approved for use through June 30, 2025 and Expires 07/28/2026.

Faculty of Health Sciences **Research Ethics Committee**

15 September 2023

Approval Certificate
Annual Renewal

Dear Miss TR Grobler,

Ethics Reference No.: 582/2022 – Line 3
Title: Injury-related medical encounters during the 2019 SkyRun races and the associated risk factors for injury

The **Annual Renewal** as supported by documents received between 2023-08-21 and 2023-09-13 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2023-09-13 as resolved by its quorate meeting.

Please note the following about your ethics approval:

- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2024-09-15.
- Please remember to use your protocol number (582/2022) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

On behalf of the FHS REC, Dr R Sommers
MBChB, MMed (Int), MPharmMed, PhD
Deputy Chairperson *of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria*

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)

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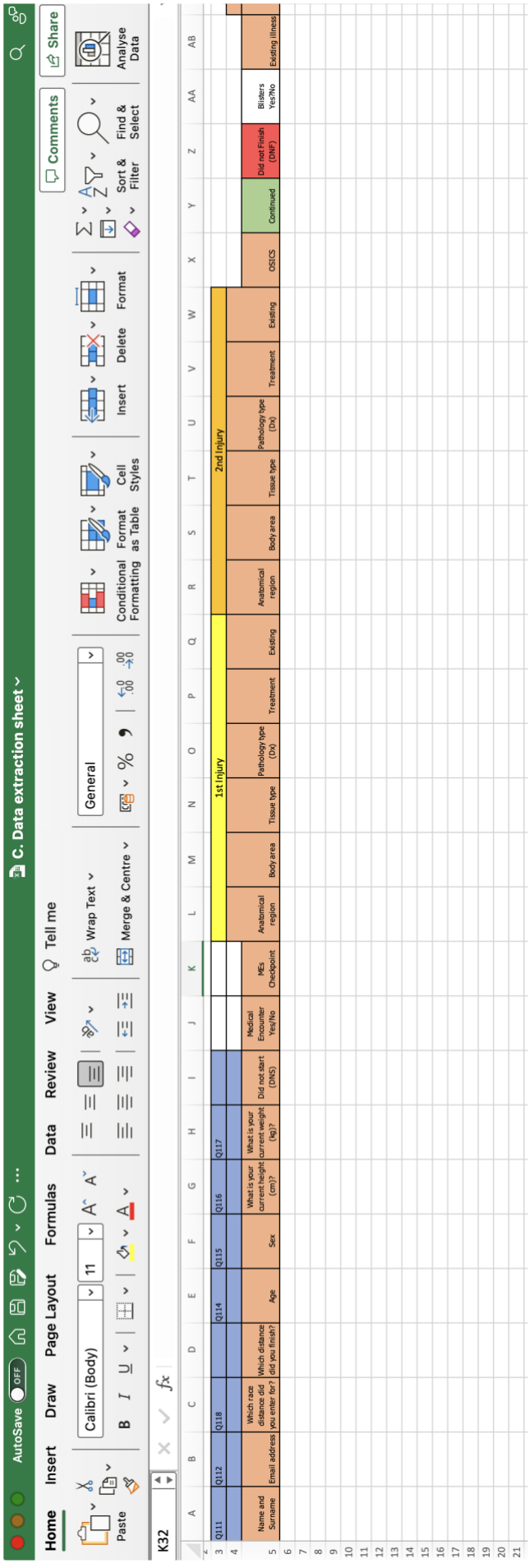
Fakulteit Gesondheidswetenskappe
Lefapha la Disaense tša Maphelo

ANNEXURE C: Data extraction sheet



ANNEXURE D: Letter of permission to access clinical records

Dr Christina de Villiers
Address
South Africa
03 Aug 2022

To: Chair: Masters Committee/ Research Ethics Committee
University of Pretoria

LETTER OF PERMISSION TO ACCESS CLINICAL RECORDS FOR RESEARCH

This letter is to confirm that I, Dr Christina de Villiers, is the medical director of the SkyRun race and custodian of the clinical records related to medical encounters during the race.

A master's student, Tyla Grobler (student number: 16007833), will be conducting a study (Injury-related medical encounters during the 2019 SkyRun races), in fulfilment of an MPhysT degree at the University of Pretoria.

I hereby give permission that the student can conduct novel research on the raw dataset, and therefore can access the clinical records to extract medical encounter data that were collected on race day in 2019.

Please feel free to contact me if any further information is required.

Yours sincerely

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ANNEXURE E: Plagiarism declaration

Plagiarism declaration

Full names	Tyla Rose Grobler
Student number	16007833
Topic of work	Injury-Related Medical Encounters During the 2019 SkyRun Races

Declaration

1. I understand what plagiarism is and am aware of the University's policy in this regard.
2. I declare that this thesis (e.g. essay, report, project, assignment, dissertation, thesis, etc.) is my own original work. Where other people's work has been used (either from a printed source, internet or any other source), this has been properly acknowledged and referenced in accordance with the requirements as stated in the University's plagiarism prevention policy.
3. I have not used another student's past written work to hand in as my own.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.

Signature