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Development of a Trail Running Injury Screening Instrument (TRISI)

A thesis submitted in fulfilment of the requirements for the degree Doctor of Philosophy in Physiotherapy

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DECLARATION

I, the undersigned, declare that the dissertation hereby submitted to the Vrije Universiteit Amsterdam and the University of Pretoria for the degree Doctor of Philosophy in Physiotherapy 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 25 day of April 2022

DEDICATION

To my wife, Carmi

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LIST OF ABBREVIATIONS

1RM	One-Repetition Maximum
AAIM	Analgesic/Anti-Inflammatory Medication
ACSM	American College of Sports Medicine
AKP	Anterior Knee Pain
BMI	Body Mass Index
CI	Confidence Interval
CNS	Central Nervous System
COPD	Chronic Obstructive Pulmonary Disease
CVD	Cardiovascular Disease
CVS	Cardiovascular System
DNF	Did Not Finish
EAC	Exercised Associated Collapse
EACPR	European Association for Cardiovascular Prevention and Rehabilitation
EAMC	Exercise Associated Muscle Cramping
EBP	Evidence Based Practice
ENT	Ear, Nose and Throat
GDPR	General Data Protection Regulation
GIS	Gastrointestinal System
GIT	Gastrointestinal Tract
GORRI	Gradual Onset Running-Related Injuries
GPS	Global Positioning System
GU	Genito-Urinary
IOC	International Olympic Committee
ITB	Iliotibial Band
ITBS	Iliotibial Band Syndrome
ITRA	International Trail Running Association
IQR	Interquartile Range
LBP	Lower Back Pain
LoE	Level of Evidence
ME	Medical Encounter
MSK	Musculoskeletal
MSUM	Multi-Stage Ultramarathon

OCEBM	Oxford Centre of Evidence Based Medicine
OR	Odds Ratio
OSTRC-H	Oslo Sports Trauma Research Centre Questionnaire on Health Problems
PAD-22	Propensity to Sports Accident Questionnaire
PFP	Patellofemoral Pain
PFPS	Patellofemoral Pain Syndrome
POPI	Protection of Personal Information
PR	Prevalence Ratio
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
PSS	Perceived Stress Scale
REC	Research Ethics Committee
RF	Risk Factor
ROF	Rating of Fatigue
RPE	Rating of Perceived Exertion
RRI	Running-Related Injuries
SAFER	Strategies to Reduce Adverse Medical Events for the Exerciser
SASMA	South African Sports Medicine Association
SD	Standard Deviation
SPF	Sun Protection Factor
TRISI	Trail Running Injury Screening Instrument
UAE	United Arab Emirates
USA	United States of America
UTI	Urinary Tract Infection
VAS	Visual Analogue Scale
WHO	World Health Organisation

CHAPTER 1

Introduction

This chapter aims to provide a background to the research project leading to the specific aims and objectives addressed in the thesis. An overview of the methodology is provided with a description of the outline of the chapters.

1. BACKGROUND

1.1. Trail running

Trail running is characterised by running outdoors, in natural environments like forests, deserts, coastal- and mountainous regions, jungles, barren plains and grasslands.[1] Within these natural environments, trail runners can be exposed to various running terrains such as dirt roads, beach or desert sand, single-track forest or mountain trails, etc.[1 2] Naturally, trail runs involve larger elevation changes as they are not limited to running on asphalt surfaces with more gradual inclines and declines. To be classified as a trail running event, the route should be limited to a maximum of 20% paved surfaces. Still, there are no restrictions on the total running distance, elevation gain, or maximum altitude.[1 2] During trail running events, runners should be self-sufficient between aid stations in terms of nutrition, gear, thermal regulation via clothing, communication, and immediate first aid.[3] However, no aid stations are available during training runs, and trail runners are expected to be self-sufficient for the whole training session duration. With regards to navigation in trail running events, the route should be clearly marked, or the runners should be able to navigate using a global positioning system (GPS) or geographical map of the specific region.[1]

Historically humans have participated in similar running activities as to what is classified as trail running today. Tribes like the Kalahari Bushmen in Southern Africa used persistent hunting techniques that involved long-distance running in natural environments while chasing down prey.[4] Over time, running evolved into a recreational activity, and various trail running events emerged in the 1970's and 1980's such as the Western States Endurance Run in the United States of America (USA) and Marathon des Sables in Morocco. In Europe, an exponential increase in trail running's popularity occurred in the early 2000's with the world's most popular race, the Ultra-trail du Mont Blanc, emerging in 2003.[3] Even though these trail running events were very popular, only in 2013, trail running was officially recognised as a sport when the International Trail Running Association (ITRA) was established and defined trail running.[1] Trail running is currently not an Olympic sport but has been recognised as an

official athletic discipline by World Athletics since 2015.[2] As one of the fastest-growing sports globally,[1 3] trail running can positively influence public health through physical activity.

Physical activity has proven health benefits in preventing and treating chronic disease[5 6] and promoting mental health.[7] Running, as a mode of physical activity, has specifically been shown to contribute to the prevention of chronic disease and premature mortality.[8] In addition, trail running as an outdoor adventure sport improved participants' perception of well-being and mental and physical health.[9] Among female trail runners, a sense of empowerment, tenacity, bravery, improved perception of resilience, and mental health have been reported.[10] Therefore, trail running participation is firmly positioned to play a key role as a cost-effective and sustainable way to contribute to physical and mental health and promote public health. However, we need to consider these health benefits in the context of injury risk and burden related to injury in trail running.

1.2. Injury in trail running

The incidence of injury in trail running has been reported to be as high as 61.2 injuries per 1000 hours of running in races[11] with training injury rates among African and European populations reported at 19.6 and 10.7 injuries per 1000 hours of running, respectively.[12 13] The majority of injuries occur in the lower limb, mainly affecting the foot/toe, ankle, and hip/groin.[14] Similar to other modes of running,[15] the majority of injuries in trail running are of gradual onset, mostly due to repetitive kinetic energy transfer during running.[14 16] Even though less common, more severe sudden onset injuries are also reported in trail running[16] for example, fractures,[17 18] ankle sprains,[19 20] meniscus injuries,[21] concussion,[22] joint dislocation[23] and subluxations,[17] and tendon ruptures.[18] Among South African trail runners, a higher mean prevalence was reported for sudden onset versus gradual onset running-related injuries (RRI).[12] Currently, research evidence is lacking to explain the exact reason for the high prevalence of sudden onset injuries and the less common severe injuries in trail running. A potential clinical explanation could be the varying uneven running surfaces that expose runners to acute joint instability episodes and blunt trauma from falling. The consequences of injury in trail running are of concern in the context of the immediate danger to the runner when acutely injured in a remote region. Also, injury can prohibit consistent access to trail running, preventing adaptation to trail running demands and access to the associated health benefits of running.

Trail runners often participate in remote regions during races and training. Medical support in these remote regions is challenging[24] not only to locate injured trail runners but also in

providing optimal treatment and emergency evacuation of injured trail runners. In remote mountain regions, fatal events have been reported in trail running training and racing.[25] The injury-related fatal events resulted from 1) blunt trauma after falling, 2) animal attack and 3) developing hypothermia after sustaining an injury where the sweat-covered runner is unable to run/hike and maintain body heat.[25] These fatal events highlight the challenges of locating injured runners accurately and reaching them in time to prevent severe adverse effects like illness following a less severe injury. In races, injured runners in need of assisted evacuations become a burden to race medical directors, who sometimes need to orchestrate multiple evacuations simultaneously. However, trail runners most frequently train in more urban regions[12 13] while sustaining less severe RRI's.[12 13] In trail running, the burden and associated medical costs of injury may threaten public health.[13] Through mitigating the injury risk, we could reduce the burden of trail running injury[13] and improve uninterrupted access to the positive health benefits of trail running. As clinicians, we need to understand better the injury risk in trail running to improve our clinical decision-making in designing individualised injury risk management strategies.

1.3. Injury risk management in trail running

A framework for injury prevention was first described in the "sequence of prevention" by van Mechelen *et al.* in 1992.[26] The model has four steps of which *Step 1* establishes the extent of injury, *Step 2* establishes aetiological mechanisms of injury, *Step 3* introduces a preventative measure based on the risk factors identified in *Step 2*, and *Step 4* assesses the efficacy and/or effectiveness of the preventative measure by repeating *Step 1*.[26] In trail running the basic epidemiology (*Step 1*) is not yet well understood with lack of prospective studies, training-related injury data, injury data related to females, and studies investigating injury among shorter distance trail runners.[16] Furthermore, there is a shortage of literature on injury risk factors in trail running[14] which forms the basis of *Step 2* that should inform *Step 3*. Even though 17 individual factors were associated with a higher risk for injury in trail running, these factors were determined through univariate analysis, using mainly cross-sectional or prospective study designs with short follow-up periods.[14] Consequently, clinicians have little guidance from research evidence in clinical decision making regarding injury risk management strategies in trail running.

Evidence-based practice (EBP) involves clinical decision-making using the best available research evidence, in combination with the clinical expertise of the clinician, in the context of the values and preferences of the patients' values and preferences[27] (Figure 1).

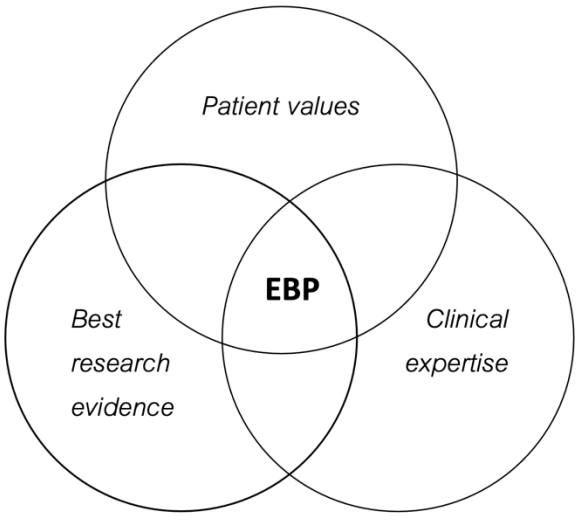

Figure 1: A schematic presentation of evidence-based practice (EBP)

Due to the absence of strong research evidence, clinicians rely heavily on their clinical experience in designing trail running injury risk management strategies. Building research evidence is a lengthy process, and in the interim, the immediate injury risk and the consequences of injury in trail running cannot be ignored. A proposed solution in cases where we have low-quality evidence to answer clinical questions may be to consider experts' opinions, clinical practice guidelines, or positions statements, [28] based on the clinical experience of experts in a specific field.

In trail running, very little expert guidance on the design of injury risk management strategies exists. Hoffman et al. (2014) published consensus guidelines for pre-race medical planning and special medical consideration at ultra-endurance races in remote environments.[24] In these guidelines, the authors highlighted the importance of pre-race medical screening and runner education.[24] However, which factors to screen, and what the content of runner education should be are still unclear. These guidelines are specifically aimed at race participation[24] with no guidance on managing injury risk during a normal training cycle. In the light of weak research evidence and the immediate need for better risk management in trail running racing and training, I consider improving on the clinical expertise component of EBP (Figure 1).

Even though trail running is rapidly growing in popularity, it is still a relatively new and small sport.[1] Smaller participant numbers translate into fewer clinicians gaining valuable clinical experience in the field. Clinicians can be assisted in the clinical decision-making process concerning trail running injury risk management by utilising current experts' knowledge in the field. In this context, we propose using a clinical decision aid to guide clinicians through an injury screening process to identify areas of priority that can be addressed with individualised injury risk management strategies.

Bahr (2016) criticised the ability of an injury screening test to predict injury.[29] The author rightfully pointed out that screening tests lack the needed test properties and that there is a sizeable overlap in test results of injured and non-injured athletes. Considering the complexity of sports injuries,[30] and the multiple varying environmental factors in trail running,[1 2] it is unlikely that one can predict injury in trail running at this stage. However, we need to be cautious of throwing out screening as a periodic health assessment based on limited injury prediction abilities. Injury screening can be important for the individual trail runner's health through timely identification of elevated injury risk in trail runners.[31] It provides clinicians with the opportunity to interact with a runner and perform a baseline health assessment which provides a chance for individualised intervention in the context of the specific trail runner.[29] Regular screening can further help avoid making clinical decisions only based on a single snapshot in time[31] accounting for the temporality of injury risk factors.[30]

Considering the complexity of sports injury[30] and the fact that the context in which these injuries occur matters,[32] a need to develop a clinical decision aid regarding injury risk management arose. We acknowledge that there is little guidance from research evidence on which factors to screen. Therefore, we deemed it necessary to use the knowledge of experts in the field of trail running injury management, to develop clinical decision aid. Currently, no clinical decision aid exists in trail running.

This PhD-project aimed to develop a trail running injury screening instrument (TRISI) through human judgment modelling to aid clinicians in estimating the injury risk among trail runners.[33] The TRISI is not aimed at predicting injury. It was developed to identify priority areas of increased risk among trail runners, which clinicians can target in injury risk management strategies in combination with their clinical reasoning.

2. AIMS AND OBJECTIVES OF THIS THESIS

2.1. Phase 1

Aim: To determine the epidemiology of injury and associated injury risk factors among trail runners.

Objective 1: To determine the epidemiology of injury (incidence and prevalence) among trail runners biweekly, over six months, using self-reported injury data collected online with the Oslo Sports Trauma Research Centre questionnaire on health problems (OSTRC-H).

Objective 2: To determine the associated injury risk factors using self-reported injury data collected online with the OSTRC-H and participants' feedback on factors they perceive as being associated with a higher risk of injury.

Objective 3: To identify risk factors associated with running-related injuries through a literature search.

Objective 4: To determine the epidemiology of injury (incidence and prevalence) and associated injury risk factors from previously collected pre-race medical screening data at the 2012-2015 Two Oceans Trail Runs.

2.2. Phase 2

Aim: To develop the TRISI based on injury risk factors relevant to the context of trail running.

Objective 1: To reach a consensus among a panel of experts in trail running regarding the potential injury risk factors to consider for developing the TRISI.

Objective 2: To incorporate, through Human Judgement Modelling, opinions from a panel of experts regarding the relative importance of the injury risk factors under consideration.

Objective 3: To develop a comprehensive the TRISI, weighted according to the expert panel's opinion on which factors contribute more to injury in trail running.

2.3. Phase 3

Aim: To identify, review and frequently update the current research evidence on associated injury risk factors in trail running to keep the TRISI updated as new literature emerges.

Objective 1: To systematically identify and review the literature on trail running injury risk factors through a living systematic review.

Objective 2: To update the literature on injury risk factors in trail running through an updated literature search bi-annually over five years.

3. THESIS OUTLINE

The structure of the thesis is as follows:

Chapter 2 is a systematic review of injury and illness epidemiology among trail runners. This chapter determined a baseline for the epidemiology of injury and helped identify the gaps in research evidence regarding injury in trail running. These gaps included limited prospective studies with longer follow up periods, limited data on training-related injuries, and a lack of injury data on shorter distance race participation.

Chapter 3 addressed two of the gaps in the literature identified in *Chapter 2* by prospectively investigating the epidemiology of injury and associated injury risk factors among trail runners over six months. This chapter also addressed *Objectives 1* and *2* of *Phase 1*.

Chapter 4 investigated the epidemiology of gradual onset injury and associated injury risk factors among trail running race entrants of 10km and 22km races over four years. A retrospective cross-sectional study was performed, analysing an existing dataset to determine. This chapter addressed *Objective 4* of *Phase 1* and one of the research gaps identified in *Chapter 2*.

Chapter 5 describes the development of the TRISI through a multi-methods approach that utilised quantitative research designs. This chapter addressed *Objectives 2* and *3* of *Phase 1* and *Objectives 1* to *3* of *Phase 2*.

Chapter 6 is a living systematic review on injury risk, and epidemiology of injury in trail running. This review was implemented to provide an up to date summary of the current research evidence to guide future updates of the TRISI. This chapter addressed *Objectives 1* and *2* of *Phase 3*.

Chapter 7 is a general discussion that summarises the findings of *Chapters 2* to *6* in the context of other relevant literature and the larger aim of this thesis.

Table 1 outlines how the aims and objectives are addressed within each phase and specific chapters in this thesis.

Table 1: Aims and objectives addressed in the chapters of this thesis

			Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6
Phase 1	Aim		x	x	x	x	
		Objective 1		x			
		Objective 2		x		x	
		Objective 3				x	
		Objective 4			x		
Phase 2	Aim					x	
		Objective 1				x	
		Objective 2				x	
		Objective 3				x	
Phase 3	Aim						x
		Objective 1					x
		Objective 2					x

x: Indicates the aim and/or objective addressed in a specific chapter of this thesis

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CHAPTER 2

Epidemiology of Injury and Illness Among Trail Runners: A Systematic Review

Published as:

Viljoen CT, Janse van Rensburg DC, Verhagen E, van Mechelen W, Tomás R, Schoeman M, Scheepers S, Korkie E. Epidemiology of Injury and Illness Among Trail Runners: A Systematic Review. Sports Med. 2021 May;51(5):917-943. doi: 10.1007/s40279-020-01418-1. Epub 2021 Feb 4. Erratum in: Sports Med. 2022 Jan;52(1):191-192.

PUBLICATION DETAILS

Title of publication:

Epidemiology of injury and illness among trail runners: A systematic review

Journal (ISSN):	**Impact factor (2020):**	**Date published:**
Sports Medicine (0112-1642)	11.140	04 February 2021

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CONFRERENCE PRESENTATION DETAILS

Title:

Epidemiology of injury and illness among trail runners: A systematic review

Conference:

IOC Conference on Prevention of Injury and Illness in Sport

Location:

Monte Carlo, Monaco

Date:

25-27 November 2021

Type of presentation:

Poster

ABSTRACT

Title: Epidemiology of injury and illness among trail runners: A systematic review

Background: Trail running is characterised by large elevation gains/losses and uneven varying running surfaces. Limited information is available on injury and illness among trail runners to help guide injury and illness prevention strategies.

Objective: The primary aim of this review was to describe the epidemiology of injury and illness among trail runners.

Methods: Eight electronic databases were systematically searched (MEDLINE Ovid, PubMed, Scopus, SportsDiscus, CINAHL, Health Source: Nursing/Academic, Health Source: Consumer Ed., and Cochrane) from inception to November 2020. The search was conducted according to the PRISMA statement and the study was registered on PROSPERO international prospective register of systematic reviews (CRD42019135933). Full text English and French studies that investigated injury and/or illness among trail runners participating in training/racing were included. The main outcome measurements included: trail running injury (incidence, prevalence, anatomical site, tissue type, pathology type/specific diagnosis, severity), and illness (incidence, prevalence, symptoms, specific diagnosis, organ system, severity). The methodological quality of the included studies was assessed using an adapted Downs and Black assessment tool.

Results: Sixteen studies with 8644 participants were included. Thirteen studies investigated race-related injury and/or illness and three studies included training-related injuries. The overall incidence range was 1.6-4285.0 injuries per 1000 hours of running and 65.0-6676.6 illnesses per 1000 hours of running. The foot was the most common anatomical site of trail running injury followed by the knee, lower leg, thigh, and ankle. Skin lacerations/abrasions were the most common injury diagnoses followed by skin blisters, muscle strains, muscle cramping, and ligament sprains. The most common trail running illnesses reported were the gastro-intestinal tract (GIT), followed by the metabolic, and cardiovascular systems. Symptoms of nausea and vomiting related to GIT distress and dehydration were commonly reported.

Conclusion: Current trail running literature consists mainly of injury and illness outcomes specifically in relation to single-day race participation events. Limited evidence is available on training-related injury and illness in trail running. Our review showed that injury and illness are common among trail runners, but certain studies included in this review only focused on dermatological injuries (e.g. large number of feet blisters) and GIT symptoms. Specific areas

for future research were identified that can improve the management of trail running injury and illness.

1. INTRODUCTION

Physical activity has established health and well-being benefits.[1 2] Participation in regular physical activity decreases the risk for premature all-cause mortality, development of chronic disease and is effective in management of a current chronic disease.[1-3] Running is a popular mode of physical activity due to its easily accessible nature, with no need for specialised equipment or requirement of specific facilities.[4 5] Some evidence suggests that physical activity in outdoor environments have a higher positive impact on mental well-being compared to indoor activity.[6] Trail running involves running outdoors on off-road terrains, often in remote geographical regions and has shown exponential growth in popularity.[7-9] Although running participation has proven health benefits[2] a high risk for injury remains.[10]

The International Trail Running Association (ITRA) defines a trail run as a race run on foot on a clearly marked route, that is usually set in a natural environment and on varying natural terrains such as mountains, deserts, forests or plains, with a maximum of 20% of the total route run on paved road [https://itra.run/content/definition-trail]. Participants preferably had to have completed the route with self-sufficiency or semi self-sufficiency with regards to clothing, communication, and nutrition [https://itra.run/content/definition-trail]. In these settings, trail runners are exposed to environmental hazards, which include: water crossings, extreme weather, insect-borne infections, and wildlife.[11] Due to the logistical challenges of providing medical care in remote regions, distressed runners, who sustain an injury or who suffer from illness, will often receive delayed medical care in comparison to road running events.[11 12] Inexperienced runners are often unaware of the physical demands and risks involved in trail running, which has resulted in serious injury, illness, and even death.[13]

Previous studies, including systematic reviews, have largely focused on the epidemiology of road running related injury (RRI) outcomes.[5 10 14-18] The application of these results to trail running seems problematic due to the nature of trail running that requires a specific endurance effort affected by large elevation gains/losses, environmental conditions, altitude, distance covered, and uneven surfaces.[19] Increased effort is required to constantly adapt to the changing running surface, resulting in the body being exposed to increased physiological and biomechanical stress.[19 20] The uneven running surfaces and related risk for ankle sprains,[21] increase the risk for falling and sustaining acute injuries, such as concussions, contusion,[22] and lacerations.[21] The larger volume of eccentric muscle work, especially in downhill running, has further shown to decrease muscle performance and increase muscle damage, compared to running on level surfaces.[23] Therefore, the injury profile and injury risk factors in trail running

may differ from road running, justifying special considerations regarding injury and illness among this population.

Considering the environmental factors and large endurance requirements, illness is another risk that trail runners face. Krabak et al. (2011) reported an incidence rate of 2.0 major medical illnesses per 1000 hours of running and 4.5 minor medical illnesses per 1000 hours of running during an off-road multistage ultramarathon.[24] In training for trail running races, training loads will often increase in preparation for the extreme conditions trail runners will face, which subsequently may increase the trail runner's susceptibility to illness.[25] Among road runners, an existing pre-race acute systemic illness was associated with unsuccessful attempts to finish a race.[26] Distressed road runners that cannot further continue with running, can easily be reached by medical staff compared to trail runners participating in remote regions. This justifies the need for clear information specifically on illness among trail runners.

The increasing insight into demand and potential hazards of outdoor sports have highlighted the need to understand how injury and illness present among trail runners. This systematic review aimed to describe the epidemiology of injury and illness in trail runners. Insight to these issues at hand will guide future research by building baseline data and will inform the development of interventions regarding the management of injury and illness risk among this specific mode of running.

2. METHODS

2.1. Data sources and search

In this systematic review, we identified eight electronic databases relevant to our research topic and performed a search from inception to November 2020. The databases searched included MEDLINE Ovid, PubMed, Scopus, SportsDiscus, CINAHL (Cumulative Index to Nursing and Allied Health Literature), Health Source: Nursing/Academic, Health Source: Consumer Ed., and Cochrane. The search was done according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement[27] and the study was registered on PROSPERO International prospective register of systematic reviews (CRD42019135933).

Two groups of keywords were used. The first group included all the different terminologies and variations of the trail running activity, while the second group included all the different words for epidemiology, injury, and illness. After using the OR operator in each group to

retrieve as many articles as possible, the two groups were combined with the AND operator in order to narrow down to the topic, as shown in the online supplementary material (S1). The only limiters used in some of the database searches were restricted to language (English or French), and humans.

After retrieving the articles, duplicates were removed. The remaining records' titles and abstracts were independently reviewed by (CTV) and (EV) to identify relevant studies. Full text of the relevant articles was retrieved and further reviewed for eligibility by (CTV) and (CJVR) to determine the final selection of studies. The references of the selected studies were reviewed to ensure no relevant articles were missed.

2.2. Study selection

Studies were included if they aimed to investigate injury or illness among trail runners, while participating in races or training. Both self-reported injury/illness data and data on medical encounters (ME's) were included in this review as defined by Schwellnus et al.[28] Including self-reported injury/illness data allows reporting on a broader scope of injuries/illnesses as not all runners will report their injury/illness to a medical professional.[29] Subsequently studies investigating biomarkers relating to possible injury or illness in the absence of participants reporting injury or illness were excluded. Participants were recognised as trail runners if they had participated in a race or training that was defined as a trail run according to the definition of the ITRA.[30] Studies were excluded if the running surface did not meet the definition of a trail run according to the ITRA. In cases of uncertainty the race's websites were accessed to determine if a specific study was investigating a trail run. Certain "ultramarathon" studies were excluded if no clear evidence of it being a trail run was available. For training-related studies, the authors had to specify that a sample of trail runners was investigated. No limit was placed on the geographical region of participation, age and the sex of participants or publication date. Case reports, case-series, conference proceedings, editorials, commentaries, opinion-based papers, and reviews were excluded. An Excel spreadsheet was used to keep detailed tracking of the study selection process. No specific systematic review software tools were used during the study selection process.

2.3. Data extraction

Extracted data from the final selection of studies consisted of: study design, year of study, population (sample size, age, sex), race/training distance, study location, aim of the study,

injury/illness definition duration/follow-up, injury outcomes (incidence, prevalence, anatomical site, tissue type, specific diagnosis, severity), and illness outcomes (incidence, prevalence, symptoms, specific diagnosis, organ system, severity). Data were extracted by five reviewers: (CTV), (CJVR), (EV), (RT), and (MS). Each reviewer received a random sample of articles from which to extract data. One reviewer (CTV) independently extracted data from all the articles for quality control, while another reviewer (CJVR) did quality control of the sample of studies (CTV) extracted data from.

2.4. Quality evaluation

The level of evidence of all the articles was determined using the Oxford Centre of Evidence Based Medicine (OCEBM) model.[31] The modified Downs and Black Quality Assessment Tool was used to rate the quality of evidence under the categories of reporting, external validity, internal validity –bias, internal validity – confounding (selection bias) and power.[32] The Downs and Black quality assessment tool was modified by removing questions related to interventions done as studies included in this review used observational study designs. The modified Downs and Black quality assessment tool consisted of four sections which assessed the quality of reporting of the results (items 1, 2, 3, 6, 7, 9 and 10), external validity (items 11 and 12), internal validity (16, 17, 18, 20, and 26) and power (item 27). The maximum total score on the tool was 25, with a higher total score indicating a higher quality of evidence for the specific study. The quality and level of evidence were assessed independently by two authors [quality assessment done by (CTV) and (EK), and level of evidence done by (CTV) and (MS)] and the extracted data were summarised for the final selection of articles (online supplementary material S2). Any discrepancies between the two authors were resolved through consensus by all authors.

2.5. Data analysis

Data analysis was in the form of reporting on variables extracted from the included studies. The incidence of injury/illness was reported per 1000 hours of running or per 1000 runners with confidence intervals (90% or 95% CI), while the prevalence or mean prevalence of injury/illness were reported as % of injured/ill runners. The frequency of injury (n, %) was reported for the categories of anatomical site, tissue type, and pathology type/specific diagnosis. The frequency of illness (n, %) was reported for the categories of illness symptoms, organ system involved, and specific diagnosis. For injury/illness severity the frequency (n, %) and mean severity scores were reported. Attempts were made to combine comparable data,

however, not all studies reported on all the variables of injury or illness among trail runners. The injury and illness outcomes were grouped by study design and training vs. race participation. Due to the heterogeneous nature of the studies included, a meta-analysis could not be performed.

3. RESULTS

3.1. Identification of studies

The search produced 4830 records, as shown in our PRISMA flow diagram (Figure 1). After all duplicates were removed, 2887 records remained. The titles and abstracts of these records were evaluated according to the eligibility criteria and 2722 records were excluded. The remaining 165 full-text articles were then reviewed, and 16 studies met the inclusion criteria.

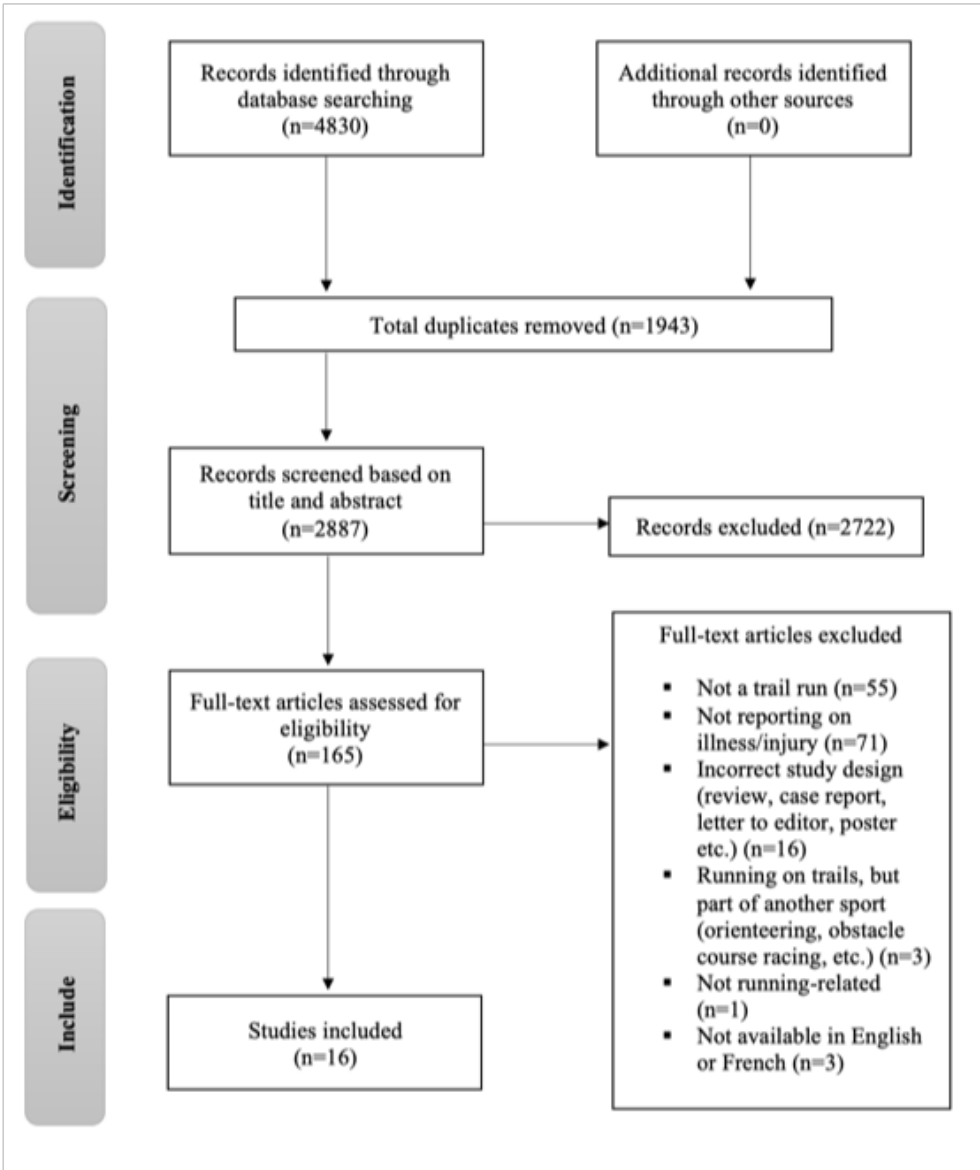

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram

3.2. Study characteristics

The 16 included studies had a publication date range from 1990 – 2020 and are summarised in Table 1. Injury/illness related to race participation were studied in 13 studies[8 21 22 24 33-41] and four of these studies[22 24 35 41] included data of multiple races. Only three studies[9 42 43] included training-related injury outcomes. Studies reported either on *injury and/or illness related outcomes* using different *injury/illness definitions* and *study designs*.

Eleven studies[8 9 21 22 24 35-37 41-43] investigated injury related outcomes and similarly, 11 studies [8 21 22 24 33-36 38-40] investigated illness related outcomes. Five of the 16 included studies reported on both injury and illness related outcomes. [21 22 24 35 36]

Injury/illness definitions mainly consisted of ME's or self-reported injuries. With regards to race participation, five studies investigated ME's [21 22 24 36 41] and eight studies used questionnaires to collect data on self-reported injuries.[8 33-35 37-40] Among the three included training related studies[9 42 43], both ME's and self-reported injuries were reported on.

Data was mainly collected using cross-sectionally [8 22 37 38 41 42] or prospectively with short follow-up periods[21 24 33 34 36 39 40] among race participation studies. One study reported on two different races and collected data both cross-sectionally and prospectively with a short follow-up period.[35] Among the three studies[9 42 43] that included training-related injury outcomes, two studies used cross-sectional designs[42 43] and one study used a prospective cohort study design over a 6-month period[9]). The difference in injury and illness definition and study designs limited our ability to group and compare results.

A total of 8644 participants was studied with an age range of 18-75 years (mean age range of 33-49.9 years). Data on sex was available for 3533 participants. The review included predominantly males (n=2771; 78.4%; versus 762 females; 21.6%).

3.3. Quality assessment and level of evidence

The mean score of the quality assessment was 8/15 (range 5-10). The quality assessment for each study is presented in the online supplementary material (S2). The interrater reliability had an observed agreement of 80%, with a Cohen's kappa value of 0.59. During the quality assessment, item 3 and 9 were most commonly scored as "no", while items 26 and 27 were rated most commonly as "unable to determine". The level of evidence of the 14 included articles were rated as level 2b, using the OCEBM model.[31] The level of evidence rating of each article is presented in Table 1.

Table 1: Characteristics of the 16 included studies

Author and publication date	Investigated Injury/illness	Data collection	Setting	No. of participants	Mean age	Gender	BMI	Level of evidence	Quality assessment
Graham et al. (2012)[36]	Injury and Illness	Prospective: recorded injury and illness data, twice per day over a 7-day period. Only recorded data of participants that required medical attention	Ultramarathon (7-day stage race) in the Gobi desert, China. Total distance of 150 miles (241 km)	11	33 (± 11)	Males: 100% (n=11) Female: 0% (n=0)	24 (± 1.79)	2b	8/15
Krabak et al. (2011)[24]	Injury and Illness	Prospective: Data recorded daily over a 7-day period, during each race. No post-race follow-up	4 Ultramarathons (7-day stage race) in the Gobi Desert, China (2005 & 2006), Sahara Desert, Egypt (2005) and Atacama Desert, Chile (2006). (240 km)	396	40 (±. 10.6) (18-64)	Males: 79.2% (n=314) Female: 20.8% (n=82)	Not reported	2b	10/15
Scheer and Murray (2011)[21]	Injury and Illness	Prospective: Data recorded daily at medical tents during a 5-day ultramarathon stage race. No post-race follow-up	Ultramarathon (5-day stage race) in Spain. Al Andalus Ultratrail	69	Males: 46 (27-63) Females: 40 (25-50)	Males: 70% (n=48) Females 30% (n=21)	Not reported	2b	8/15
McGowan et al. (2015)[22]	Injury and Illness	Race-day medical encounter data recorded by medical staff at aid stations during a 161km race (2010-2013). Observational	Western States Endurance Run, California, United States of America. (161km)	1563	2010: 43 ±10 (18–75), 2011: 43 ±10 (22–74), 2012: 42 ±10 (23–77), 2013: 42 ±10 (22–70)	2010 (total n=423): Males: 79.7% (n=337) 2011 (total n=375): Males 81.3% (n=305) 2012. (total n=382): Males 81.9% (n=313) 2013 (total n=383): Males 79.9% (n=306)	Not reported	2b	9/15
Vernillo et al. (2016)[8]	Injury and Illness	Cross-sectional: Data recorded via a questionnaire at the end of the race. No follow-up	Vigolana Trail Run (65km) in Trento, Italy	77	43.6 (± 10.9)	Males: 83% (n=64) Females: 17% (n=13)	Not reported	2b	9/15
Costa et al. (2016)[35]	Injury and Illness	Data were collected at two races via a questionnaire (self-reported): MSUM*: Prospective: Data recorded over 4 days at the end of each stage. Continuous marathon (24hr): Cross-sectional: Data recorded at the end of the 24-hour race	Data were collected at two races: Al Andalus Ultimate Trail race in Lojo, Spain (2010 & 2011) Glenmore24 Trail Race in the Scottish Highlands (2010 & 2011)	MSUM: 54 24hr: 22	MSUM: 40 (± 8) 24hr: 40 (± 7)	MSUM: Males: 61% (n=33) Females: 39% (n=21) 24hr: Males: 73% (n=16) Females: 27% (n=6)	Not reported	2b	8/15
Hespanhol Junior et al. (2017)[9]	Injury	Prospective: Data recorded every 2 weeks over a 6-month period	Dutch trail runners participating in trail running in the Netherlands	228	43.4 (42.2-44.6)	Males: 75% (n=171) Females: 25% (n=57)	22.6 (22.3-22.8)	2b	10/15

Malliaropoulos et al. (2015)[42]	Injury	Cross-sectional: Data recorded via a questionnaire. No follow-up	Ultratrail runners residing in Greece	40	39.4 (22-59)	Males: 90% (n=36) Females: 10% (n=4)	23.35 (± 1.99)	2b	8/15
Hoffman and Stuempfle (2015)[37]	Injury	Cross-sectional: Data on muscle cramping recorded with online questionnaire post-race. No follow-up.	Western States Endurance Run, California, USA**. (161km)	280	Whole sample not specified	Whole sample not specified	Complete detail of the sample not specified	2b	9/15
González-Lázaro et al. (2020)[41]	Injury	Cross-sectional: Medical encounter injury data recorded via a self-reported participant form. Data were collected over 5-years (2015-2019) at 36 different races. No follow-up.	36 different mountain running races, Spain. (20-42km)	4831	40 (±7)	Males: 91% Females: 9%	Not reported	4	5/15
Matos et al. (2020)[43]	Injury	Cross-sectional: Sel-reported injuries recorded via an online questionnaire. No follow-up.	Portuguese trail runners.	719	38.01 (±7.78)	Males: 74% (n=529) Females 26% (n=190)	Not reported	2b	9/15
Banfi et al. (1996)[33]	Illness	Prospective: GIT*** symptoms recorded during and after the run. Self-reported during questioning	Marathon (Second Fila Skymarathon) on the Tibetan Plateau. 42 km, 4300m mean altitude	13	35 (SD 8)	Males: 100% (n=13) Female: 0% (n=0)	21 (SD 1.2)	2b	6/15
Stuempfle et al. (2016)[40]	Illness	Prospective: Recorded data on GIT*** distress at 46km, 90km, 126km and 161km.	Western States Endurance Run, California, USA**. (161km)	20	Not reported	Males: 75% (n=15) Females: 25% (n=5)	Not reported	2b	8/15
Stuempfle and Hoffman (2015)[38]	Illness	Cross-sectional: Participants completed a questionnaire post-race (between 1-15 days) to report on symptoms in the four distance categories of the race.	Western States Endurance Run, California, USA**. (161km)	272	41 (± 9.6)	Males: 79.4% (n=216) Female: 21.6% (n=56)	Not reported	2b	8/15
Stuempfle et al. (2013)[39]	Illness	Prospective: Data recorded data on GIT*** distress at every 25km loop of the 161km race.	Javelina Jundred 100 mile Endurance Run in Arizona, USA**. (161km)	15	Symptoms: 44 (26-52), no symptoms: 49.9 (37-67)	Males: 67% (n=10) Females: 33% (n=5)	Not reported	2b	7/15
Baska et al. (1990)[34]	Illness	Prospective: Data recorded data on GIT*** symptoms both pre and post-race 161km race.	Old Dominion 100 Mile Endurance Run in Virginia, USA**	34	39.8 (± 8)	Males: 97% (n=34) Females: 3% (n=1)	Not reported	2b	5/15

Abbreviations: *MSUM (multi-stage ultramarathon), **USA (United States of America), ***GIT (gastrointestinal tract)

3.4. Injury and illness outcomes

Injury outcomes are presented under the categories of injury definition, duration/follow-up periods, anatomical site of injury, tissue type, pathology type/specific diagnosis, and severity of injury (Table 2). Illness outcomes are presented under the categories of duration/follow-up periods, illness definition, symptoms, organ system involved, specific diagnosis, and illness severity (Table 3). Reporting of injuries and illnesses were based on the definitions used by authors of the included articles.

Due to the difference in study designs and follow-up periods, especially among the injury studies, the results are categorised in: 1) studies that recorded race-related injuries;[8 21 22 24 35-37] 2) cross-sectional study design that included training-related injuries:[9] and, 3) prospective cohort study design that included training-related injuries.[42] Even though some race-related injury studies prospectively collected data, they are grouped with the cross-sectional study designs, due to their extremely short follow-up periods.

Table 2: Trail running injury-related outcomes (race and training participation)

Author and publication date	*Injury definition*	*Follow-up*	*Injury site/anatomical region*	*Tissue type*	*Pathology type / Specific diagnosis*	*Severity*	*Incidence / Prevalence*
Cross-sectional and prospective studies with short follow-up periods (included only race participation injury outcomes)							
Graham et al. (2012)[36]	Medical encounter: Injury sustained during the race, reported to medical staff	Multi-stage event (seven stages, 241km): Data recorded twice per day over a seven-day period	Knee Achilles tendon Shin Feet	Skin Soft tissue Tendon	Abrasion: 100% (n=11) Blisters: 100% (n=11)	Not reported	Not reported
Krabak et al. (2011)[24]	Medical encounter: Disability sustained during the race that resulted in a medical encounter at medical checkpoint (every 10km and finish line)	Multi-stage events (four different events): Data recorded daily over a seven-day period, during each of the four events.	MSK [a] and skin Injuries 92.6% lower limb: Foot (73.7%) Lower leg (8.6%) Ankle (4.9%) Knee (3.5%)	MSK [a] Bursa (n=12) tendon (n=222)	Bursitis (n=12) Sprain (n=27) Strain (n=28) Tendonitis (n=122) Abrasion (n=43) Blister (n=652) Cellulitis (n=9) Hematoma (n=107) Other (n=55)	Severity definition: Major: unable to continue in race Minor: able to continue in race Minor injuries: - MSK [a] and skin injuries: minor (n=1029) Major injuries: - MSK [a] and skin injuries: major (n=26)	Injury rates per 1000 runners (95% CI) - All: 3871.3 (3652.9-4049-3) - MSK [a] (major): 46.2 (25.2-77.5) - MSK [a] (minor): 670.0 (581.0-768.7) - Skin (major): 39.6 (20.4–69.2) - Skin (minor): 2726.1 (2543.3-2918.5) Injury rates per 1000 h of running (95% CI) - All 65.0 (61.4-68.7) - MSK [a] (major): 0.8 (0.4-1.3) - MSK [a] (minor): 11.2 (9.8-12.9) - Skin (major): 0.7 (0.3-1.1) - Skin (minor): 45.8 (42.8–48.9)

Author and publication date	*Injury definition*	*Follow-up*	*Injury site/anatomical region*	*Tissue type*	*Pathology type / Specific diagnosis*	*Severity*	*Incidence / Prevalence*
Scheer and Murray (2011)[21]	Medical encounter: All self-referred clinical encounters with the medical team	Multi-stage event (five stages): Data recorded daily during a five-day ultramarathon stage race.	Number of consultations: Hip (n=3) Knee (n=9) Ankle (n=6) Achilles (n=2) Related to chafing and blisters: No of consultations unknown. Upper leg, lower leg, subungual, groin, foot	Bursa (hip) Cartilage (knee) Tendon (Achilles and ankle) Muscle (upper and lower leg) Soft tissue (under nail) Skin	Trochanteric bursitis (n=3) Patellofemoral pain syndrome (n=9) Achilles tendinopathy (n=2), Ultramarathoner's ankle (n=1) Ankle inversion injury (n=5) Quadriceps muscle pain (n=1) Tibialis Anterior muscle pain (n=1) Blisters (n=33), Chafing (n=9), Subungual hematoma (n=2), Laceration (n=1), Muscle cramps (n=3), Dog bite (n=2)	DNF [b] (n=4), further severity not defined or reported	Reported an overall incidence for participants seeking medical advice (injury and illness) = 56.5%
Costa et al. (2016)[35]	Self-reported: Dermatology symptoms reported to trained researchers (standardised interview)	Multi-stage event – four stages (MSUM [c]): Data recorded prospectively over four days at the end of each stage. Single stage event (continuous marathon): Data recorded at the end of a 24-hour race	Foot	Skin	Blisters	Not reported	Not reported
McGowan et al. (2015)[22]	All medical encounters at race aid station	Single stage event (161km): Race-day data recorded by medical staff at aid stations each year (2010-2013).	Unknown	Unknown	Sprain, strain or tendinitis n=7 (0.9%) Muscle cramping n=6 (0.8%) Muscular pain n=5 (0.7%) Contusion n=2 (0.3%) Concussion n=1 (0.1%) Skin wound n=1 (0.1%) Visual impairment n=1 (0.1%)	20 runners not able to finish the race, 6 cases due to injury	Not reported

Author and publication date	*Injury definition*	*Follow-up*	*Injury site/anatomical region*	*Tissue type*	*Pathology type / Specific diagnosis*	*Severity*	*Incidence / Prevalence*
Vernillo et al. (2016)[8]	Self-reported medical encounters at race finish	Single stage event (65km): Data recorded using a questionnaire post-race.	Ankle n=16 (28.6%) Knee n=8 (14.3%) Thigh n=8 (14.3%) Neck/Spine n=4 (7.1%)	Tendon n=20 (35.7%) Ligament n=24 (42.9%) Muscle n=12 (21.4%)	Cramps n=16 (26.2%), Plantar fasciitis n=16 (28.6 %), Ankle sprain n=16 (28.6%), Achilles tendinopathy n=4 (7.1%), Knee sprain n=8 (14.3%), Thigh strain n=8 (14.3%), Neck/cervical spine strain n=4 (7.1%), Laceration n=2 (15.4%), Subungual hematoma n=2 (15.4%), Chafing n=2 (15.4%), Foot blisters n=7 (53.8%)	Not reported	Total injuries and illnesses (n=132) Injury rates per 1000 runners (90% CI): MSK [a]: 614.3 (559.0-761.7) Skin: 314.3 (286.0-389.7) Injury rates per 1000 hours (90% CI): MSK [a]: 4285.0 (3899.3-5313.4) Skin: 2192.3 (1994.9-2718.4)
Hoffman and Stuempfle (2015)[37]	Self-reported muscle cramping, without clear given definition of muscle cramping	Single stage event (161km): Data recorded via a questionnaire 1-15 days post-race.	Calf (57.5%), Quadriceps (57.5%), Hamstring (45.0%), Hip flexors (17.5%), Trunk (10.0%), Hip adductors (2.5%), Ankle dorsiflexors (7.5%), Forearm (7.5%), Foot (5.0%), Upper arm (2.5%), Hand (2.5%)	Muscle	Muscle cramping	Not reported	Not reported
González-Lázaro et al. (2020)[41]	Medical encounters: Injuries sustained during a race that required medical attention. Major injury = the runner was not able to further participate in the race. Minor injury = the runner could continue with race participation.	Single stage events (20-42km): Date recorded at 36 different races using a self-reported participant form.	Ankle (32%) Knee (14%) Foot/toe (11%) Upper limb (18%) Trunk (7%)	Not reported	Not reported	Major injury (25%) Minor injury (75%)	Total number of injured partcipants (n=28) Injury rates: 5.9 injuries per 1000 runners 1.6 injuries per 1000 hours of running.
Prospective cohort study design (included training-related injury outcomes)							

Author and publication date	*Injury definition*	*Follow-up*	*Injury site/anatomical region*	*Tissue type*	*Pathology type / Specific diagnosis*	*Severity*	*Incidence / Prevalence*
Hespanhol Junior et al. (2017)[9]	Self-reported: Disorder of the musculoskeletal system which were sustained or experienced whilst running. Substantial RRIs [d] were defined as any injuries leading to moderate or major reductions in training volume or running performance	Training: Data collected. prospectively every two weeks over a six-month period	Lower leg n=49 (20.6%) Knee n=44 (18.9%) Foot n=36 (14.9%) Achilles n=31 (12.8%) Pelvis/hip/groin n=25 (10.3%) Upper leg n=23 (9.5%) Ankle n=22 (9.1%) Lower back n=5 (2.1%) Chest n=2 (0.8%) Wrist/hand n=2 (0.8%) Multiple regions n=3 (1.2%)	Muscle n=67 (27.7%) Tendon n=57 (23.6%) Ligament n=18 (7.4%) Bone n=13 (5.4%) Fascia n=9 (3.7%), skin n=8 (3.3%), cartilage n=7 (2.9%), joint (multiple tissues) n=2 (0.8%), nerve n=2 (0.8%), bursa n=1 (0.4%), unknown n=58 (24.0%)	Achilles tendon injury n=31 (12.8%), calf muscle trigger points/ spasm n=26 (10.7%), knee pain undiagnosed n=21 (8.7%), ankle sprains n=17 (7.0%), buttock muscle strain n=10 (4.1%), foot pain undiagnosed n=10 (4.1%), muscle strain lower limb (crossing anatomical boundaries) n=9 (3.7%), hamstring strain n=8 (3.3%), plantar fasciitis strain n=8 (3.3%), ITB [e] syndrome n=7 (2.9%), tenoperiostitis of lower leg n=7 (2.9%), blisters foot n=5 (2.1%), knee tendon injury n=5 (2.1%), lower leg pain undiagnosed n=5 (2.1%), hip/groin pain undiagnosed n=4 (1.7%), patellar tendinopathy n=3 (1.2%), lumbar pain undiagnosed n=3 (1.2%), patellofemoral pain n=3 (1.2%), thigh muscle strain/ spasm/ trigger points n=3 (1.2%)	Severity defined according to number of days lost to train at full capacity, according to the OSTRC [f] questionnaire Median severity score was 35.0 (25–75 %, IQR [g] 22.0–55.7), and the median of the duration of RRIs [d] was 2.0 weeks	Total number of injuries (n=242) Mean prevalence (95% CI) of RRIs: 22.4 % (20.9–24.0), and Injury rate (95 % CI): 10.7 RRIs injuries rate per 1000 h of running (95 %: CI 9.4-12.1).
Cross-sectional study design (included training-related injury outcomes)							

Author and publication date	*Injury definition*	*Follow-up*	*Injury site/anatomical region*	*Tissue type*	*Pathology type / Specific diagnosis*	*Severity*	*Incidence / Prevalence*
Malliaropoulos et al. (2015)[42]	Self-reported: Symptomatic with or without medical attention	Training: Data recorded cross-sectionally via a questionnaire.	Low back (42,5%) Hip (35.0%) Thigh (anterior) (5.0%) Thigh (posterior) (30.0%) Thigh (lateral) (35.0%) Thigh (medial) (20.0%) Knee (40.0%) Leg (anterior) (27.5%) Leg (posterior) (22.5%) Achilles tendon (20%) Foot dorsal (27.5%) Foot plantar (32.5%)	Not specifically reported	Only 31.85% of the injuries were diagnosed by a medical doctor Total injuries (n=135) Spinal disc injuries (14%) Hamstring strain (12%) ITB [e] (16%) Meniscus injuries (14%) Tibiofibular joint injury (2%) Adductor tendonitis (2%) Overuse bone stress injuries (22%) Achilles tendonitis (7%) Morton's Neuroma (5%) Plantar fasciitis (7%)	Severity definition: Grade 1 – symptoms that appear after running Grade 2 – appear hours after running Grade 3 – appear during running Grade 4 – chronic symptom Total injuries (n=135): Grade 1: 50.4% (n=68) Grade 2: 1.5% (n=2) Grade 3: 10.4% (n=14) Grade 4: 37.8% (n=51)	Total number injuries (n=135) Prevalence: 90% of runners reported at least on injury
Matos et al. (2020)[43]	Self-reported injuries via an online questionnaire.	No follow-up	Hip n=97 (4.5%), Spine (cervical zone) n=30 (1.4%), Spine (dorsal zone) n=25 (1.2%), Spine (lumbar zone) n=98 (4.5%), Anterior thigh n=108 (5%), Posterior thigh n=103 (4.8%), Thoracic zone (chest) n=11 (0.5%), Leg n=192 (8.9%), Knee n=377 (17.5%), Ankle n=312 (14.5%), Toes n=173 (8%), Ears n=9 (0.4%), Toenails n=535 (24.8%), Other n=85 (3.9%)	Not reported	Blisters n=554 (20%), Shin splints n=122 (4%), Contusion n=92 (3%), Luxation n=65 (2%), Sprains n=318 (11%), Plantar fasciitis n=108 (4%), Bone fracture n=22 (1%), Stress fracture n=30 (1%), Irritation (chafing) n=387 (14%), Superficial wound n=321 (12%), ITB [e] n=181 (7%), Patellofemoral syndrome n=78 (3%), Acilles tendinitis n=94 (3%), Thendinitis (other zones) n=108 (4%), Tendon strain n=35 (1%), Muscle strain n= 66 (2%), Micro strains n=126 (5%), Other 77 (3%)	Not reported	Total number of injured partcipants (n=631) Injury rate per 1000 hours of running All: 10.0 Males: 10.13 Females: 9.62

Abbreviations: [a] MSK (musculoskeletal), [b] DNF (did not finish), [c] MSUM (multi-stage ultramarathon), [d] RRIs (running-related injuries), [e] ITB (iliotibial band), [f] OSTRC (Oslo Sports Trauma Research Centre), [g] IQR (interquartile range)

3.5. Injury

3.5.1. Anatomical site

All injury-related studies: The foot as injured site occurred in nine studies[9 21 24 35-37 41-43] followed by the knee in eight studies,[8 9 21 24 36 41-43] lower leg in seven studies,[9 21 24 36 37 42 43] thigh in six studies,[8 9 21 37 42 43] and ankle in six studies.[8 9 21 24 41 43]

Race participation studies: Four studies reported the foot as the most common site of injury[21 24 35 36], although one study reported exclusively on dermatological injuries that mainly involved the foot.[35] All studies that were open to reporting any injury, indicated the knee as an injured site.[8 21 24 36 41] During a multi-stage ultramarathon, Scheer and Murray (2011) reported that complaints of the knee were responsible for the highest number of musculoskeletal consultations [21], while two studies reported the knee as the second most commonly injured site following the ankle.[8 41] The lower leg as injury site were reported among four studies.[21 24 36 37] The ankle was noted as a common injury site among trail runners.[21, 18, 8 41] Scheer and Murray (2011) reported the ankle as the second most commonly injured site, with acute ankle inversion sprains accounting for 83.3% of ankle injuries.[21] Similar results were found by Vernillo et al. (2016) (28.6%) and González-Lázaro et al. (2020) (32%) who reported the ankle as the most commonly injured site among trail runners that participate in mountainous terrains.[8 41] The thigh as site of injury was reported by three studies.[8 21 37] The thigh (14.3%) presented to be just as commonly injured as the knee (14.3%) in the study of Vernillo et al. (2016), while the thigh muscles were also the most frequently reported site of cramping.[37] Two studies focussed on either cramping[37] or dermatological injuries,[35] while one study did not specify the anatomical site of injury.[22]

Training/race participation studies: The only prospective cohort study included in this review that, indicated the lower leg (20.6%) as the most frequently injured anatomical site, followed by the knee (18.2%), and foot (14.9%).[9] Two cross-sectional studies among Greek and Portuguese trail runners, who mostly ran on mountainous trails, were included.[42 43] Among Greek trail runners[42] the most prevalent injury site was the thigh (90.0%), followed by the lower back (42.5%), and the knee (40.0%) while among Portuguese trail runners[43] the foot/toe (24.8%), knee (17.5%), and ankle (14.5%) were the most prevalent sites of injury.

Interesting sites of injury noted, not reported in road running literature, include the neck/spine[8] during races, and chest and wrist/hand[9] injuries during training.

3.5.2. Tissue type and pathology type/specific diagnosis

Race participation studies: Abrasions, lacerations and skin wounds occurred in five studies [21] [18] [19] [31] [8] while blisters and chafing were reported in three studies.[21] [18] [31] Two of the studies reported exclusively on dermatological injuries[35] [36], with 100% of participants in the Graham et al. (2012) study having blisters and abrasions.[36] In three studies, muscle strains and spasms were reported affecting only the lower limb muscles, specifically of the quadriceps and tibialis anterior muscle groups.[18] [19] [8] Muscle cramping was reported in four studies.[8] [21] [22] [37] One study reported on muscle cramping only, with the highest frequency noted in the calf (57.5%), quadriceps (57.5%), and hamstring (45.0%) muscles.[37] In two studies, acute ankle sprains were among the top five most frequently reported injury [18] [8] with Scheer and Murray (2011) specifically referring to ankle inversion injuries recorded.[21] Common lower limb overuse injuries, such as Achilles tendinopathy,[18, 8] patellofemoral pain syndrome (PFPS),[21] and plantar fasciitis [8, 34] were also reported at trail run races. Across all specific musculoskeletal injuries recorded by Scheer and Murray (2011), PFPS (9.1%) showed the highest frequency.[21]

Training/race participation studies: In a prospective cohort study, Hespanhol Junior et al. (2017) reported an overuse injury, namely Achilles tendinopathy (12.8%) as the most common injury among 228 Dutch trail runners.[9] The second most common injury reported was calf muscle trigger points/ spasm (10.7%), followed by undiagnosed knee pain (8.7%), ankle ligament sprains (7.0%), plantar fasciitis (3.3%), PFPS (1.2%), and iliotibial band (ITB) (2.9%). Lacerations/abrasions that were the highest reported injuries on race-day, were not frequently noted among a sample of runners where training injuries were also studied.[9] Among the two cross-sectional studies that also included training related injury outcomes,[42] [43] different injury patterns were reported. Overuse bone stress injuries (22.0%), followed by ITB injuries (16.0%) were the most commonly reported injuries among Greek trail runners,[42] while dermatological injuries including blisters (20%) and chafing (14%) were most commonly reported among Portuguese trail runners.[43]

In this review other injuries were noted, which have not been reported in road running literature. These injuries include: concussion, contusions,[22] and cervical spine strain[8] recorded at races, and spinal disc injuries, tibio-fibular joint injury, and knee meniscus injury[42] recorded during training.

3.5.3. Injury severity

Race participation studies: Injury that resulted in discontinuation of a race was rated as major in two studies.[24 41] Krabak et al. (2011) reported that major musculoskeletal injuries presented with an incidence rate of 0.8 injuries per 1000 hours of running,[24] but the majority of all MEs (97.4%) were minor in nature, with specifically minor musculoskeletal injuries showing an incidence rate of 11.2 injuries per 1000 hours of running.[24] González-Lázaro et al. (2020) reported that 25% of all injuries were major.[41] Other studies did not define injury severity, but still reported on runners that did not finish the race.[21 22] Scheer and Murray (2011) reported four runners not being able to finish the race due to knee pain, blister pain, and muscle cramps.[21] In the study of McGowan et al. (2015) injury severity was not defined, but 20 runners did not finish the race: six due to sprains, strains, concussion, and muscle cramping.[22]

Training/race participation studies: Among the three studies that included training-related injuries,[9 42 43] only two studies reported on injury severity.[9 42] Hespanhol Junior et al. (2017) graded severity based on the onset of symptoms and used a severity grading system of symptoms that: 1=appear after running; 2=appear hours after running; 3=appear during running, and; 4=chronic symptoms. Grade 4 injuries accounted for 37.77% of all injuries, however, grade 1 injuries (50.37%) were mostly recorded.[42] The other training-related study[9] focused on how the presenting symptoms affected the participants' ability to run and used a severity grading established by Clarsen et al. (2013), as derived from the Oslo Sports Trauma Research Centre (OSTRC) questionnaire.[44] Substantial injuries were defined as "those leading to moderate or major reductions in training volume, moderate or major reductions in running performance, or complete inability to run". An incidence rate of 5.8 substantial injuries per 1000 hours of running was reported.[9] Even though higher severity injuries were noted, it remained far less frequently reported compared to the minor injuries.

Table 3: Trail running illness-related outcomes (race participation)

Author and publication date	*Illness definition*	*Follow-up*	*Organ system*	*Symptoms*	*Specific diagnosis*	*Severity*	*Total number of illnesses Incidence / Prevalence*
Graham et al. (2012)[36]	Medical attention: Injury sustained during the race, reported to medical staff	Multi-stage event (seven stages, 241km): Data recorded, twice per day over a seven-day period	Metabolic	Not reported	Heat stress: 100% (n=11) Heat exhaustion: 54% (n=6)	Not reported	Not reported
Krabak et al. (2011)[24]	Medical attention: Disability sustained during the race that resulted in a medical encounter at medical checkpoint (every 10km and finish line)	Multi-stage event (four different events): Data recorded daily over a seven-day period, during each of the four stages.	Respiratory CNS [a] CVS [b]	Not reported	EAC [c] (n=78) Altitude sickness (n=11) Serious medical diagnosis (n=2) Other (n=27)	Severity definition: Major: unable to continue in race Minor: able to continue in race Illness: - Major (n=36) - Minor (n=82)	Illness rates per 1000 runners (95% CI [d]) - All: 3871.3 (3652.9-4049.3) - Medical (major): 118.8 (83.2-164.4) - Medical (minor): 270.6 (251.2-355.9) Illness rates per 1000 hours of running (95% CI [d]) - All: 65.0 (61.4-68.7) - Medical (major): 2.0 (1.4-2.8) - Medical (minor): 4.5 (3.6-5.6)
Scheer and Murray (2011)[21]	All self-referred clinical encounters with the medical team over 5 days, from the start of the first stage to the end of the race	Multi-stage event (five stages): Data recorded daily during a 5-day ultramarathon stage race. No post-race follow-up	Metabolic CNS [a] CVS [b] ENT [e] GU [f] Immunological	Number of consultations: Palpitations (n=3) Fatigue (n=3) Vomiting (n=4) Headache (n=1)	EAC [c] Dehydration Allergy/hay fever Epistaxis Dog bite Haematuria UTI [g]	DNF [h] (n=5), further severity not defined or reported	Reported an overall incidence for participants seeking medical advice (injury and illness) = 56.5%

Author and publication date	*Illness definition*	*Follow-up*	*Organ system*	*Symptoms*	*Specific diagnosis*	*Severity*	*Total number of illnesses Incidence / Prevalence*
McGowan et al. (2015)[22]	All medical encounters at race aid station	Single stage event (161km): Data recorded by medical staff at aid stations each year (2010-2013).	Metabolic ENT [e] CVS [b]	Nausea vomiting n=15 (2.0%) Severe fatigue n=1 (0.1%)	Respiratory distress n=7 (0.9%) Hypothermia n=5 (0.7%) Dehydration n=4 (0.5%) Overhydration n=2 (0.3%) Allergic reaction n=1 (0.1%) Cardiovascular issue n=1 (0.1%) Hyponatraemic seizure n=1 (0.1%)	DNF [h] n=20, n=14 (1.9%) due to illness Race performance affected in 40.1% of participants Nausea/vomiting n=3 Respiratory distress n=4 Hypothermia n=5 Dehydration n=1 CVS [b] issue n=1	Not reported
Vernillo et al. (2015)[8]	Self-reported medical encounters at race finish	Single stage event: Data recorded using a questionnaire post-race.	Metabolic ENT [e]	Fatigue n=23 (37.7%) Palpitations n=2 (3.2%) Vomiting n=6 (9.8%) Headache n= 6 (9.8%)	Hypothermia n=1 (1.6%) Allergy/hay fever n=2 (3.2%) Dehydration n=4 (6.6%)	Not reported	Illness rates per 1000 runners (90% CI): Medical: 957.1 (871.0-1 186.8) Illness rates per 1000 hours (90% CI): Medical: 6676.6 (6075.7-8278.9)
Banfi et al. (1996)[33]	Self-reported symptoms of GIT [i] distress	Single stage event (65km): Data recorded during and post-race	GIT [i]	During the run: Nausea n=4 (31%) Side ache n=2 (15%) After the run: Nausea n=8 (62%) Vomiting n=2 (15%) Diarrhoea n=2 (15%)	Not reported	Not reported	Not reported
Stuempfle et al. (2016)[40]	Self-reported: Participants reported symptoms at checkpoints during the race	Single stage event (161km): Data recorded at checkpoints during the race and the finish	GIT [i]	Nausea (60%) Belching (45%) Flatulence (35%) Urge to defecate (30%) Vomiting (25%) Stomach cramps/pain (20.0%) Loose stool/diarrhoea (15%) Stomach bloating (15%) Reflex/heartburn (10%) Side ache/stitch (10%) Intestinal cramps/pain (5%)	Not reported	Severity rating: "None", "mild", "moderate", "severe" or "very severe" were converted to numeric values 0, 1, 2, 3 and 4 for analysis of symptom severity. Mean ± SD nausea severity was 1.6 ± 0.7 with a range of 1-3.	Total number of participants reporting illness (n=16) Prevalence: 80% of runners reported an illness

Author and publication date	*Illness definition*	*Follow-up*	*Organ system*	*Symptoms*	*Specific diagnosis*	*Severity*	*Total number of illnesses Incidence / Prevalence*
Stuempfle and Hoffman (2015)[38]	Self-reported symptoms of GIT [i] distress	Single stage event (161km): Data recorded via a questionnaire 1-15 days post-race	GIT [i]	Flatulence (65.9%) Belching (61.3%) Nausea (60.3%) Stomach bloating (48.7%) Urge to defecate (47.6%), Vomiting (35.4%) Stomach cramps/pain (31.9%) Intestinal cramps/pain (24.1%) Loose stool/diarrhoea (22.2%) Side ache/stitch (20.4%) Reflex/heartburn (11.8%) Intestinal, bleeding/bloody stools (1.5%)	Not reported	Severity rating: "none", "mild", "moderate", "severe" or "very severe". Negative for a symptom if they answered "none". "None", "mild", "moderate", "severe" or "very severe" were converted to numeric values 0, 1, 2, 3 and 4 for analysis of symptom severity. Stomach cramps/pain (mean value 1.1) and intestinal cramps/pain (mean value 1.1) had the highest severity ratings	Prevalence: 96% of runners reported an illness
Stuempfle et al. (2013)[39]	Self-reported: Participants reported symptoms of GIT [i] distress at checkpoints during the race	Single stage event (161km): Data recorded after every 25km loop	GIT [i]	Frequency: Nausea 89% Abdominal cramps 44% Diarrhoea 44% Vomiting 22%	Not reported	Not reported	Total number of participants reporting illness (n=9) Prevalence: 60% of runners reported an illness
Baska et al. (1990)[34]	Self-reported: Pre and post-race questionnaire, Stool samples - 3 week prior, and first 3 post-race	Single stage event (161km): Data recorded one week before, up to seven days post-race	GIT [i]	GIT [i] bleeding Positive n=29 Negative n=5	GIT [i] bleeding	Not reported.	Not reported

Author and publication date	*Illness definition*	*Follow-up*	*Organ system*	*Symptoms*	*Specific diagnosis*	*Severity*	*Total number of illnesses Incidence / Prevalence*
Costa et al. (2016)[35]	Self-reported: GIT [i] and Dermatology symptoms reported to trained researchers (standardised interview)	Multi-stage event – four stages (MSUM [j]): Data recorded prospectively over four days at the end of each stage. Single stage event (continuous marathon): Data recorded at the end of a 24-hour race	GIT [i]	GIT [i]: Nausea, urge to vomit, vomiting, belching, bloating, stomach pain, gastric acidosis, abdominal pain, constipation, diarrhoea	Not reported	Not reported	MSUM [j] Prevalence: 85% of runners reported an illness

Abbreviations: [a] CNS (central nervous system), [b] CVS (cardiovascular system), [c] EAC (Exercise-associated collapse), [d] CI (confidence interval), [e] ENT (ear nose and throat), [f] GU (Genito-urinary), [g] UTI (urinary tract infection), [h] DNF (did not finish), [i] GIT (gastrointestinal tract), [j] MSUM (multi-stage ultramarathon), [k] GIS (gastrointestinal symptoms)

3.6. Illness

3.6.1. Organ system

Six studies specifically investigated illness symptoms related to GIT distress and did not report on other illnesses.[33-35 38-40] The metabolic system was reported on in four studies,[8 21 22 36] followed by the cardiovascular system(CVS)[21 22 24] and, ear nose and throat (ENT) system[8 21 22] that were both accounted for in three of the illness-related studies. Other less frequently involved organ systems included the respiratory,[24] central nervous (CNS),[21 24] genito-urinary, and immunological systems.[21]

3.6.2. Illness symptoms and specific diagnosis

Common GIT symptoms recorded were nausea, vomiting, diarrhoea, abdominal cramping, and pain.[8 21 22 33 35 38-40] Although less frequent, flatulence, side aches, belching, constipation and GIT bleeding were also reported.[33 35 38 40] Other symptoms reported included palpitations, headaches, and severe fatigue.[8 21 22]

Specific diagnosis of dehydration was indicated by three studies reporting on ultramarathon trail illnesses[8 21 22] and Graham et al. (2012) described heat exhaustion in a desert multi-stage ultramarathon.[36] Exercise-associated collapse (EAC) was described at a seven-day stage race and during the Western States 161km race with no fatalities.[21 24] Krabak et al. (2011) studied a race with trails going up to 4300m above sea level and is the only study that diagnosed altitude sickness among participants.[24] Other illnesses diagnosed included: hypothermia,[8 22] allergic reactions,[8 21 22] respiratory distress, cardiovascular event, hyponatraemic seizure,[22] haematuria, epistaxis, and urinary tract infection.[21]

3.6.3. Illness severity

An inability to complete a race due to illness was rated as major severity by Krabak et al. (2011).[24] An incidence rate of 2.0 major illnesses per 1000 hours of running was recorded, where the majority was due to EAC.[24] Scheer and Murray (2011) reported five runners not finishing the race due to palpitations, sickness, and fatigue.[21] During the 2010-2013 Western States Endurance Run, two cases of emergency evacuation were reported due to bronchospasm and hyponatraemic seizure, but 55% of runners that had a medical consultation were still able to complete the race.[22]

Even though severe illness related MEs were reported, the majority of illnesses were minor. Specifically referring to GIT illness severity, Stuempfle et al. (2016) used a grading system of 0-4; referring to none=0, mild=1, moderate=2, severe=4. Nausea was reported at a mean of 1.6, indicating mild to moderate severity.[42] A similar severity scale was used by Stuempfle and Hoffman (2015) and they found the highest severity for stomach and intestinal cramps/pain at mean values of 1.1. each.[38]

4. DISCUSSION

To our knowledge, this is the first systematic review examining injury and illness among a trail running population. The findings of this systematic review need to be interpreted in the context of the limited literature available: mainly cross-sectional study designs at single-day events; race-related injury/illness focus; and inconsistent definitions of injury/illness across studies. The fact that certain studies had a single illness/injury focus may overestimate the foot as the most common anatomical site of injury and GIT symptoms as the most common illness reported. This review included predominantly middle-aged male runners, participating in ultramarathon trail run races. The considerable heterogeneity regarding study designs and injury definitions used among the included studies prevented strong conclusive findings regarding the epidemiology of injury and illness among trail runners. Despite the heterogeneity of the included studies, we could present an integrated discussion regarding similar characteristics of injury (anatomical location, tissue/pathology type, severity) and illness (symptoms, diagnoses, severity).

The main injury findings of this review are: 1) the foot, knee, lower leg, thigh and ankle are the most common anatomical sites of injury; 2) Skin lacerations/abrasions, followed by skin blisters, muscle strains, muscle cramping, and ligament sprains are the most common injury diagnoses, and; 3) most injuries are of minor severity. The main illness findings of this review are: 1) the GIT, followed by the metabolic, and CVS are the most common organ system involved; 2) symptoms of nausea and vomiting were most commonly reported with GIT distress and dehydration diagnosed most common, and: 3) most illnesses were of minor severity. These outcomes were reported among the 14 included studies (six studies reported on both injury and illness, three studies reported on injuries only, and five studies on illnesses only) that investigated trail running, as a sub-category of off-road running. [45]

4.1. Sub-categories of off-road running

Running on off-road surfaces have different sub-categories as per definition from the various sports governing bodies/federations. Some of these sub-categories include fell running, skyrunning, mountain running, and trail running.[45] The term "off-road running" only refers to running on natural surfaces (unsealed) with no specific reference to distance, percentage of total running surface to be off-road, terrain, elevation, distance, etc. However, trail running as defined by the ITRA[46] has the most encompassing definition that gives clarity of the running surface, terrain, support, route markings, and has no limitations regarding elevation or distance. Therefore, we decided to use the trail running definition as according to the ITRA to guide inclusion of studies into this systematic review.

4.2. Injury and illness definitions

Studies included in this review used a variety of methods and definitions to record and report on injury and illness. All injury/illness definitions met the requirements of either MEs or self-reported injuries/illnesses.[28 29] A 2019 consensus statement that addressed the issue of definitions and recording of MEs at endurance sports events, defined a ME as a medical problem reported to the event medical team; i.e. not a self-reported injury or illness questionnaire. Schwellnus et al. (2019) also acknowledged that athletes can develop a medical problem during a race and can choose not to report their medical problems to the event medical team.[28] This was defined as a non-reported medical problem.[28] Self-reported injury/illness data were also included in this review as this allowed for the inclusion of a broader scope of injuries/illnesses as indicated by the International Olympic Committee (IOC) consensus statement.[29] Changes in biomarkers as a result of trail running can/cannot result in injury/illness and therefore poses a risk of overestimating injury or illness. We therefore excluded studies that investigated biomarkers related to potential injury/illness.

4.3. Trail running injury

Similar to previous running literature,[10 16] this review indicated that the lower limb is the most commonly injured body region affecting the foot, knee, lower leg, thigh and ankle. The foot as injured anatomical site was reported by nine studies[9 21 24 35-37 41-43] and in five of these, the foot was noted as the most common site of injury.[21 24 35 36 43] However, four studies used cross-sectional designs to investigate multi-stage ultramarathons where the high frequency and magnitude of skin shears in the shoe affects the formation of foot blisters while running for

extended time periods on consecutive days.[47] Further one study solely investigated dermatological-related injuries.[35] These dermatological injuries could have resulted in an overestimation of the foot as injured anatomical site.

The knee is a known common site for overuse RRI[10 16] and this review showed similar results. Regardless of study design, race vs. training participation, running terrain, distance, and elevation change, the knee was previously reported as a common site of musculoskeletal injury.[8 9 21 24 36 41-43] During ultramarathons, Scheer and Murray (2011) reported that complaints of the knee were responsible for the highest number of musculoskeletal consultations.[21] A cross-sectional study investigating trail runners that participated in a rough mountainous region reported the knee as the second most commonly injured site following the ankle.[8] Both these studies investigated ultramarathons where fatigue can result in altered knee joint kinematics[48] and pain as a result of overuse can increase the vertical ground reaction force with further loading at the knee joint.[49] Also, increased cumulative knee joint loading is observed with a slower running pace.[50]. These factors could contribute to the knee being reported as a commonly injured site, but the multifactorial complex nature of sports injuries is important to consider.[51] Among the three studies that included training-related injuries[9 42 43] the knee was also reported as the second most commonly injured site, indicating the knee as high risk for injury regardless of racing/training, running surface or distance. Similar to previous running literature[10 16], PFPS[8 9 21 43] and ITB injuries[9 42 43] are common overuse injuries reported in this review. Even though less commonly reported, it is important to notice that acute knee injuries such as knee sprains[8] and meniscus injuries[42] were also reported in this review. This may indicate the increased multidirectional loading the knee is exposed to on more technical uneven terrains compared to road running disciplines.

Muscle injuries of the thigh were reported in five studies. [8 9 21 37 42 43] Two cross-sectional studies reported a high frequency of thigh muscle strains and both these studies investigated trail runners participating in mountainous regions.[8 42] Running in mountainous regions involves larger elevation changes, which increase the volume of eccentric muscle work, especially in downhill running. Downhill running has shown to decrease quadriceps muscle performance and to increase muscle damage, compared to running on level surfaces[23] and provides a possible explanation for the muscular thigh injuries reported. The quadriceps (57.5%) and hamstring (45.0%) muscles were also reported as two of the most common sites of injury among ultramarathon runners in another study.[37] This particular race covers a distance of 161km and runners are exposed to high temperatures resulting in fatigue. Altered

neuromuscular control that occurs during muscular fatigue is viewed as a plausible hypothesis for exercise-associated muscle cramping (EAMC). This is supported by the findings of Vernilllo et al. (2016) who also indicated cramping as the most common injury type among 65km trail runners in a mountainous region.[8] These findings highlight the need for conditioning of the thigh muscles in preparation for safe trail running participation.

The ankle was noted as a common injury site among trail runners.[8 9 21 24 41 43] During trail running races, runners are exposed to high levels of fatigue and usually run on unknown trails with uneven surfaces. This may explain the high incidence of acute ankle injuries during race participation. However, a prospective cohort study among Dutch trail runners that typically train on more level trail surfaces, still reported that 77.27% of all ankle-related injuries were ankle sprains.[9] A cross-sectional study among Greek trail runners, who mostly ran on mountainous trails, included race and training injury outcomes.[42] The authors reported the thigh as most commonly injured site, but did not report on ankle injuries as they mentioned that due to the high frequency of repetitive ankle spraining, it was impossible to assess the correct occurrence of ankle injuries using a cross-sectional study design. [42] Among trail runners participating in mountainous regions in Spain, the ankle (32%) was reported as the most common injury over 5 seasons of running.[41] These results emphasise the need for multi-directional ankle stability during training for trail running.

The lower leg as injury site, was largely due to Achilles tendinopathy, reported as common overuse injury among race participation studies[8 21 36] and training-related injuries.[9 42 43] Although the Achilles tendon is a commonly injured structure among road runners,[16] the mechanism of injury in trail running may differ. Overload of the Achilles tendon can occur during uphill and downhill trail running on routes with higher elevation changes where the calf muscle is exposed to increased load over longer periods of time.[52] Overloading of the calf is further emphasised by the reported calf muscle injuries and cramping.[9 37] Interesting to note was the high frequency of reported ankle dorsiflexor muscle cramping.[37] When running over uneven surfaces, the lower leg muscles are exposed to increased load during This can be the result of repetitive ankle dorsiflexion to prevent tripping over rocks/branches and adopted posterior patterns during downhill running[53] which increase eccentric muscle work. This may be a possible explanation for overload and cramping of the lower leg musculature.

Interesting sites of injury noted, not reported in road running literature, included the neck/spine[8 43] and chest and wrist/hand[9] injuries. The wrist and hand body regions are not exposed to overuse injury during trail running participation and therefore could be related to acute injury.

Lacerations and abrasions were diagnosed in most articles that studied trail run races[8 9 21 22 24 36] which emphasise the potential risk of falling during trail running participation. Even though the mechanism of injury was not reported in these studies, trail running is not a contact sport, therefore the likelihood of falling or impact with tree branches, rock faces, etc. should be considered as potential reasons for specifically the lacerations/abrasions and wrist/hand injuries reported. Lacerations/abrasions that are the highest reported injuries on race-day, were not frequently noted among a sample of runners where training injuries were also studied.[9] This could be an indication of higher risk taken among race participants with a subsequent increased risk for falling. Hespanhol Junior et al. (2017) studied Dutch trail runners that are typically training on more level running surfaces, which could be an explanation for the lower frequency of lacerations/abrasions as result of potential falling.[9] Currently there is a lack of prospective cohort studies investigating trail runners pertaining to training and race participation and therefore a comparison between race participation and training-related injuries is challenging.

Various gradings were used to report injury severity. Minor injuries were more frequently reported compared to serious injuries. However, there were cases of runners that were unable to continue with a race.[21 22 41] It is important to note that in the context of trail running, any injury that limits the runner's ability to keep moving has serious implications as these runners enter remote regions, are semi-/self-sufficient, exposed to extreme weather conditions, and medical care is challenging. Future studies should follow the consensus guidelines of reporting injury severity,[28] which will allow for comparison between studies.

4.4. Trail running illness

The most commonly reported organ system affected across all illness studies was the GIT. Common GIT symptoms recorded were nausea, vomiting, diarrhoea, abdominal cramping, and pain.[8 21 22 33 35 38-40] Although less frequent, flatulence, side aches, belching, constipation and GIT bleeding were also reported.[33 35 38 40] The fact that GIT distress is common amongst trail runners need to be interpreted in the context of this review that included mostly studies investigating ultramarathons. Nutritional errors during prolonged exercise in ultra-endurance races, easily result in GIT distress.[54] A further limitation to this finding is that six of the nine studies specifically investigated illness symptoms related to GIT distress and did not report on other illnesses [33-35 38-40]. This could have resulted in an overestimation of GIT-related illness among trail runners. Dehydration was common among ultramarathon runners during race participation [8 21 22] and could contribute to nausea as a common symptom. Graham et al. (2012)

described heat exhaustion in a desert multi-stage ultramarathon.[36] Stuempfle et al. (2016) also reported that the severity of nausea increased during higher temperature segments of the race.[40] As trail running is a self-sufficient or semi self-sufficient sport,[55] it can be concluded that participants could easily mismanage their amount of carried fluids, leading to dehydration.

Exercise-associated collapse (EAC) was described at a seven-day stage race and during the Western States 161km race with no fatalities.[21 24] Considering the challenges of medical care in remote regions,[12] EAC is of real concern considering the prolonged time for medical staff to reach a distressed runner. Krabak et al. (2011) studied a race with trails going up to 4300m above sea level and is therefore the only study that diagnosed altitude sickness among participants.[24] Two studies reported hypothermia.[8 22] The first part of the Western States Endurance Run crossed over snow covered mountains, however, no specific detail on the Italian trail studied by Vernillo et al. (2016)[8] is available to explain the potential cause of hypothermia.

Allergic reactions were also reported.[8 21 22] Allergies are commonly reported among endurance athletes[56] and trail runners may perhaps have higher exposure due to environmental pollens, dust, and potential insect bites in natural environments. Additional illnesses diagnosed included respiratory distress, cardiovascular event, hyponatraemic seizure,[22] haematuria, epistaxis, and urinary tract infection.[21] Other symptoms reported included palpitations, headaches, and severe fatigue.[8 21 22]

Similar to the injury-related studies, various gradings for illness severity were used in the absence of a guiding consensus statement of reporting on illness severity.[28] In this review the majority of illnesses were graded as minor with serious illnesses noted only amongst ultramarathon trail runners.[21 22 24] Preparation for ultramarathons includes several months of training and possibly motivate runners to try and reach the finish line at all cost, exposing them to high physiological demands. This was evident during the 2010-2013 161km Western States Endurance Run, where two cases of emergency evacuation were reported due to bronchospasm and hyponatraemic seizure, but 55% of runners with a ME still completed the race.[22]

4.5. Limitations

Even though an extensive search strategy was used in this review, the search was restricted to English and French language.

The difference in injury and illness definitions and study designs limited our ability to group and compare results. Injury and illness definitions included ME's and self-reported injuries/illness. During race participation, a runner's main goal is to finish the race. Runners will likely continue to run even though injured or experiencing illness and only report more severe injury/illness to medical staff. Therefore, ME data might under report injury/illness and overestimate the severity of injury/illness. Self-reported data is potentially exposed to recall bias as a result of the recall period, and social desirability bias regarding honest reporting of sensitive data such as injury status.[57]

Our review mainly included cross-sectional studies that reported on injuries and illnesses related to race participation at single-day events. Few studies recorded injuries using similar injury definitions over time. This could have resulted in acute injuries being over presented in this review and thus providing limited insight into overuse injury related to training. Considering that a trail runner often needs to endure pain[58 59] over an extended period of time to complete a race, it has to be acknowledged that self-reported injury or illness associated with pain, may have been underreported in the articles included in this review.

The injury and illness severity gradings also differed amongst studies included in this review. These differences in severity gradings limited our ability to group and compare results on the impact injury and illness have on trail runners.

The foot as injury site and GIT as organ system affected were most frequently involved in injury/illness, however, certain studies included in this review only focused on dermatological injuries (e.g. large number of feet blisters) and GIT symptoms. This may have resulted in an overestimation of these reported injuries and illness symptoms.

Our results can help to guide planning injury prevention and injury risk management strategies at races, but limited evidence is available to advise the trail runner regarding training towards a race.

4.6. Recommendations for future research

This review included participants exposed to trail run races consisting of various running surfaces, distances and environmental conditions. This presents as an advantage in generalising the results to the larger trail running community that participates in races, however, comparing the results between studies is challenging. Future studies that focus on trail running race participation should attempt to clearly define their race as a trail run according to the ITRA[30]

and describe the surface, elevation change, and weather on race-day.[45] As pointed out by the Ultra Science Sports Foundation's position statement, there is a need to clearly define off-road running disciplines.[46] At this stage, events are classified according to governing bodies/federations that provide certification for races. However, not all race organisers seek certification and self-label their races according to distance (ultramarathon), popularity (trail running), altitude (skyrunning) etc. Therefore, future research should aim to clearly describe characteristics of races under investigation[46], with a smaller focus on which governing body/federation the race is hosted under. This will allow better comparisons between race-related studies.

Studies that investigate MEs at trail running races should follow the guidelines as stipulated in the 2019 consensus statement on recording and reporting of results collected at endurance events to help improve comparisons of injury and illness-related outcomes among studies.[28]

A bigger research focus is needed on prospectively recording training-related injuries and illness to help guide trail runners on prevention during preparation for races. Injury and illness among shorter distance trail runners need to be investigated as these races attract runners with very little or no experience in trail running. These runners might show different injury/illness profiles compared to experienced runners participating in ultramarathon distances.

5. CONCLUSION

Current evidence in trail running literature consists mainly of cross-sectional study designs at single-day events and focusses on injury and illness specifically in relation to race participation. Limited evidence is available on training-related injury and illness in trail running. Our review showed that, injury and illness are common among trail runners with an overall incidence range of 1.6-4285.0 injuries per 1000 hours of running and 65.0-6676.6 illnesses per 1000 hours of running. Certain studies included in this review only focused on dermatological injuries (e.g. large number of feet blisters) and GIT symptoms. Considerable heterogeneity regarding study designs and injury/illness definitions existed among the included studies. Future research should standardise definitions and study designs and report on all anatomical regions and organ systems, in both competition and training.

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Update to: Epidemiology of injury and illness among trail runners: A systematic review

https://doi.org/10.1007/s40279-020-01418-1

On 17 March 2021, an erratum was published online (https://www.thieme-connect.com/products/ejournals/abstract/10.1055/a-1400-4290) in the International Journal of Sports Medicine that showed corrected values for the incidences of injury and illness presented in the Vernillo et al. study[1]. The Vernillo et al. study was included in our systematic review[2] and therefore the following updates should be applied:

ABSTRACT

The sentence describing incidence range previously read:
"The overall incidence range was 1.6–4285.0 injuries per 1000 h of running and 65.0–6676.6 illnesses per 1000 h of running."
Updated to read:
The overall incidence range was 1.6–61.2 injuries per 1000 h of running and 65.0–95.4 illnesses per 1000 h of running.

Table 2:
Below the "Incidence / Prevalence" column of the Vernillo et al. (2016) row, the injury rate per 1000 h previously read:
"Injury rates per 1000 h (90% CI): MSK [a]: 4285.0 (3899.3–5313.4) Skin: 2192.3 (1994.9–2718.4)"
Updated to read:
Injury rates per 1000 h (90% CI): MSK [a]: 61.2 (48.0–78.1) Skin: 31.3 (22.2–44.2)

Table 3:
Below the "Incidence / Prevalence" column of the Vernillo et al. (2016) row, the illness rate per 1000 h previously read:
"Illness rates per 1000 h (90% CI): Medical: 6676.6 (6075.7–8278.9)"
Updated to read:
Illness rates per 1000 h (90% CI): Medical: 95.4 (78.8–115.5)

CONCLUSION

The concluding sentence previously read:

"Our review showed that, injury and illness are common among trail runners with an overall incidence range of 1.6–4285.0 injuries per 1000 h of running and 65.0–6676.6 illnesses per 1000 h of running."

Updated to read:

Our review showed that, injury and illness are common among trail runners with an overall incidence range of 1.6–61.2 injuries per 1000 h of running and 65.0–95.4 illnesses per 1000 h of running.

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CHAPTER 3

Epidemiology, Clinical Characteristics, and Risk Factors for Running-Related Injuries Among South African Trail Runners

Published as:

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. Int J Environ Res Public Health. 2021 Nov 30;18(23):12620. doi: 10.3390/ijerph182312620.

PUBLICATION DETAILS

Title of publication:

Epidemiology, clinical characteristics, and risk factors for running-related injuries among trail runners

Journal (ISSN):	**Impact factor (2020):**	**Date published:**
International Journal of Environmental Research and Public Health (1660-4601)	3.39	30 November 2021

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CONFRERENCE PRESENTATION DETAILS

Title:

Running-Related Injuries and Associated Risk Factors Among 151 Trail Runners Followed Over 30 Weeks: A Prospective Cohort Study

Conference:

World Physiotherapy Congress

Location:

Dubai, UAE (online)

Date:

09-11 April 2021

Type of presentation:

Platform

ABSTRACT

Trail running involves running on varying natural terrains often including large elevation gains/losses. Trail running has a high risk of injury, and runners often participate in remote regions where medical support is challenging. The aim of this study was to determine the epidemiology, clinical characteristic, and associated injury risk factors among trail runners. A modified Oslo Sports Trauma Research Center Questionnaire for Health Problems (OSTRC-H) was used biweekly to collect running-related injury (RRI) and training history data prospectively, among 152 participants (males n=120, females n=32) over 30 weeks. We report an overall injury rate of 19.6 RRIs per 1000 h and an RRI mean prevalence of 12.3%. The leading anatomical site of RRIs was the lower limb (82.9%), affecting the knee (29.8%), shin/lower leg (18.0%), and the foot/toes (13.7%). A history of previous RRI in the past 12 months (p=0.0032) and having a chronic disease (p=0.0188) are independent risk factors for RRIs among trail runners. Two in three trail runners sustain an RRI mainly affecting the knee, shin/lower leg, and foot/toes. A history of previous RRI in the past 12 months and a having chronic disease is independently associated with RRI among trail runners. These results could be used to develop future RRI prevention strategies, combined with clinical knowledge and experience.

Keywords: Off-road running; lower limb injury; history of RRI; chronic disease

1. INTRODUCTION

Trail running is an outdoor activity and one of the most popular running modes under the broader category of off-road running.[1] Trail running is defined as running in natural environments (mountains, forests, deserts, countryside, etc.) on natural variable terrain that involves a maximum of 20% paved roads and has significant elevation gains and losses.[1]

Despite the positive health benefits of running and outdoor activities, trail running presents a high risk of injury during race[2 3] and training participation.[4] The majority of trail running literature investigating injury focused on outcomes related to race participation, with limited studies reporting on training-related injuries.[5] A prospective cohort study among Dutch trail runners reported an overall incidence of 10.7 running-related injuries (RRIs) per 1000h, showing a higher incidence of overuse (8.1 per 1000h) vs acute (2.7 per 1000h) RRIs.[4] However, acute injuries, such as ankle sprains,[6] contusions, concussion,[7] tibio-fibular joint and meniscus injury[8], are also reported among both male and female trail runners.

Trail runners are often exposed to extreme weather conditions and environmental hazards when running in remote regions with limited access to medical services.[9] This highlights the need to establish injury risk management strategies among trail runners participating in races and training.[9] Major traumatic injuries receiving delayed medical care in these environments can lead to life-threatening complications and fatalities.[10] There is a lack of literature regarding injury risk factors among trail runners[8], with no prospective cohort studies. Common RRI risk factors identified in road running literature include age,[11 12] sex,[11] body mass index (BMI),[12] running experience,[8] injury history,[11 13] running frequency[11] and chronic disease.[14] A difference in physiological and mechanical stress might be present in trail running vs road running because of the various off-road-running terrains and larger elevation changes often involved in trail running.[15] It is necessary to investigate if identified road running risk factors are associated with injury risk among trail runners to guide future trail running-specific injury prevention strategies. We also need to investigate whether cross-sectionally determined injury risk factors in trail running, such as chronic disease,[16] is still significant when investigated prospectively using longer follow-up periods. Finally, factors specifically related to trail running, such as elevation gains/losses, training surface, and trail running experience have an associated risk that needs further investigation.

The aim of the study was to prospectively determine the incidence, prevalence, and clinical characteristics of RRIs among male and female South African trail runners. We also aimed to

investigate whether previously described RRI risk factors also apply to trail running and if new factors, specifically related to trail running, are associated with RRI risk.

2. MATERIALS AND METHODS

2.1. Study design

We conducted a prospective cohort study in South Africa from 20 November 2018 to 19 August 2019.

2.2. Participants and data collection

This study used a dynamic sample, allowing participants to enter the study at different time points. All participants were followed for 30 weeks. We used a convenience sampling method and recruited participants through trail running social media platforms, the South African Trail Running organisation, and TRAIL magazine. The inclusion criteria stipulated that participants had to be 18 years or older, having the ability to read and understand English, having access to email, and are training towards a trail race of 21km or more. Participants were not excluded based on the type or amount of training they were exposed to in preparation for their chosen race. Participants were excluded if they did not complete the baseline and at least one follow-up questionnaire. The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee of the Faculty of Health Sciences at the University of Pretoria (REC no: 469/2018).

Our study sample included a total of 152 participants, consisting of 78.9% males (n=120) and 21.1% females (n=32). Even though 41.4% (n=63) of runners had more than 5 years of total running experience, only 16.4% (n=25) had similar years of experience in trail running. At the study baseline, a total of 26 (17.1%) participants reported having a chronic disease including hypercholesteremia (28.9%), hypertension (21.1%), asthma (18.4%), hypothyroidism (7.9%), and diabetes (5.3%). Most participants (n=109, 71.7%) sustained an RRI in the 12 months before entering the study, while 53.8% (n=71) had a current RRI upon entering the study.

An analysis was done to determine whether the baseline data significantly differed between males and females (Table 1).

Table 1: Baseline data (demographic profile, running experience, medical history, and RRI history) of all study participants (n=152)

Characteristic		All participants (n=152)	Female (n=32)	Male (n=120)	p-value
Age (yrs) mean (SD)		37.1 (9.1)	35.9 (8.8)	37.4 (9.2)	0.4015
Height (cm) mean (SD)		177.6 (8.4)	167.8 (5.6)	180.2 (7.0)	<0.0001*
Weight (kg) mean (SD)		76.3 (11.7)	63.4 (7.3)	79.7 (10.2)	<0.0001*
BMI (kg/m^2) mean (SD)		24.1 (2.8)	22.52 (2.4)	24.6 (2.7)	<0.0001*
Total running experience n (%)	0-2yrs	37 (24.3%)	10 (31.2%)	27 (22.5%)	0.3962
	>2 to 5yrs	52 (34.2%)	8 (25.0%)	44 (36.7%)	
	>5yrs	63 (41.4%)	14 (43.8%)	49 (40.8%)	
Trail running experience n (%)	0-2yrs	66 (43.4%)	12 (37.5%)	54 (45.0%)	0.7445
	>2 to 5yrs	61 (40.1%)	14 (43.8%)	47 (39.2%)	
	>5yrs	25 (16.4%)	6 (18.8%)	19 (15.8%)	
Chronic disease n (%)	Yes	26 (17.1%)	7 (21.9%)	19 (15.8%)	0.5876
	No	126 (82.9%)	25 (78.1%)	101 (84.2%)	
Current RRI (at study entry) n (%)	Yes	71 (53.8%)	19 (63.3%)	52 (51.0%)	0.3248
	No	61 (46.2%)	11 (36.7%)	50 (49.0%)	
	Missing	20	18	2	-
Previous RRI (past 12 months) n (%)	Yes	109 (71.7%)	24 (75.0%)	85 (70.8%)	0.8071
	No	43 (28.3%)	8 (25.0%)	35 (29.2%)	

SD: Standard deviation; BMI: Body Mass Index; RRI: running-related injury.

Eligible responders received a link via email, which guided them to an online consent form and baseline questionnaire (online supplementary file 1). At baseline, we recorded their demographic profile, running experience, training history, current medical conditions, medicine use, current RRI, and history of previous RRI (past 12 months). Subsequently, participants received a link via email every second week to an online follow-up questionnaire on the Qualtrics platform (online supplementary file 2). These questionnaires recorded self-reported data on 1) the participants' biweekly training history [total running distance (km.), amount of running sessions on trails (n) and road (n), total vertical gain/loss (m.), average running pace (min./km.), average altitude trained at (m.), and amount of hours spent on cross-training (h.)], 2) RRI history (anatomical region, RRI type, gradual/sudden onset, mechanism of RRI, and to what extent did the RRI affect their running ability) was reported using a modified Oslo Sports Trauma Research Centre Questionnaire on Health Problems (OSTRC-H) questionnaire,[17] and 3) RRI severity (OSTRC severity score 0-100). Participants not responding to the email within three days received a reminder email with a specific date range, stating the two-week time period the questionnaire referred to.

2.3. Health problem registration and classification

A modified version of the OSTRC-H[17] was used to prospectively register health problems during the biweekly follow-up periods. As the OSTRC-H allows for the recording of sudden onset injury and gradual onset injury and provides additional information on the location, symptoms, and type of problem,[17] it served the purpose of our study. The OSTRC-H has a high internal consistency (Cronbach's alpha = 0.91).[17] We defined a health problem as an RRI or illness that resulted in modifying the participant's training. If a respondent reported a health problem, a follow-up question was asked that required them to specify whether their training had to be modified due to "injury" or "illness". For this study, we only reported injury-related data. Multiple factors can affect performance in trail running and not all symptoms following a trail run can be directly linked to injury. Therefore, we employed training modification as our injury definition. Participants also had to indicate whether their injury had a gradual or sudden onset and whether this was the first time they reported the specific injury through the online injury surveillance platform. A "first-time" injury was recorded as a new injury, while all other injuries (injuries reported previously during the 30 weeks follow-up period) were recorded as "recurrent" injuries. An experienced sports physiotherapist (CTV) evaluated the data of each reported injury to ensure the injury was running-related. If any clarity was needed on the reported injury, the participant was contacted to obtain further information.

2.4. Outcome measures

We reported the biweekly mean prevalence (% of runners; 95% CI) and injury rate (per 1000 hours) for new/recurring RRIs and sudden/gradual onset RRIs, over 15 two-week periods. The frequency of RRI characteristics (n; % of RRIs) was reported in the categories of the anatomical region, body area, tissue type and pathology type, as stipulated by the 2020 International Olympic Committee (IOC) consensus statement regarding methods of reporting epidemiological data on injury in sports.[18] Running-related injury severity was calculated through the OSTRC-H injury severity score (0-100), allocating a score (0-25) to each response on four key questions regarding an injury.[17] In the modified OSTRC questionnaire, four questions related to how RRI affected the participants' 1) training/race participation, 2) running performance, 3) severity of their health complaint, and 4) pain while running (online supplementary file 2, question 2-5). Each question added up to 25 contributing to a composite

score of 100. A higher OSTRC-H injury severity score indicates a higher severity of the injury.[17]

With limited available evidence regarding injury risk factors in trail running, we used common injury risk factors identified in general running literature, including the participants' demographic profile [sex, age (years),[11] BMI [12 13]], biweekly running exposure[11] [number of running sessions, hours of running, running distance (km.)], running experience[8] (years of actively participating in running), and RRI history[11 13] (current RRI and RRI during the past 12 months). Additionally, factors unique to trail running were investigated as injury risk factors: running surface (trail, road, grass, tartan, treadmill), trail running experience (years of actively participating in trail running), biweekly trail running exposure (number of trail running sessions), elevation gains/losses [biweekly ascent (m.) and descent (m.) during running sessions]. In certain urban areas of South Africa, access to trails is challenging, and trail runners may use cross-training as an adjunct training modality. Therefore, cross-training (cycling, weight training, swimming, rowing, functional strength training) were investigated as an injury risk factor in the univariate analysis. Also, chronic diseases among endurance runners are common and have displayed an associated risk for injury.[19] A history of chronic disease was thus investigated as an injury risk factor in this study.

2.5. Statistical analysis

The statistical program R was used for analysis of the data.[20] The response rate (%) for each of the two-week periods (total of 15 periods) was calculated by dividing the total number of respondents by the number of invites for each specific period and then averaged across the 15 time periods. For example, if we had only three time-periods and 100 participants were contacted, but only 80 responded in the first time-period (80/100 × 100 = 80%), 70 responded in the second time-period (70/100 × 100 = 70%), and 85 responded in the third period (85/100 × 100 = 85%), then we calculated the average over all three time periods (80 + 70 + 85 = 78.3%). Instances where participants failed to supply a response for a two-week interval, were considered a "no response" and treated as such. When calculating specific results for each of these two-week periods, the missing participants were not included in the baseline of participants for that time period. In the risk factor analysis (mixed logistic regression model) the random effect accounts for the repeated measures within each participant. Here the modelling only considered the available data.

For running exposure, the mean duration (hours) of running was calculated using the specific biweekly period's average running pace and multiplying it by the total biweekly running distance. For example, if a participant ran an average pace of 6:00 min/km and an average distance of 10 km, then the duration equals 60 min = 1 hour of running exposure. We used the non-parametric Mann Whitney U test to explore statistically significant differences between training variables of males vs females (biweekly frequency or running sessions, distance ran, and duration of running) and the Wilcoxon signed-rank test to investigate for significant differences between gradual vs sudden onset RRI variables (prevalence and injury rate) (tested at a 5% level of significance). Non-parametric tests were used since the Shapiro Wilk test found that the data was not normally distributed.

The prevalence and injury rate calculations were similar to Hespanhol Junior et al. (2017).[4] For each period (two weeks), the prevalence was calculated by dividing the number of participants reporting RRIs during that period by the total number of respondents during the specific period. The mean prevalence and the 95% CI were calculated by summing the prevalences across all two-week periods and dividing the total by the number of two-week periods. The injury rates for all new and recurrent RRIs were calculated by dividing the number of RRIs (all, new, and recurrent) by total running exposure in hours across all the periods. For each of the two-week periods, the four OSTRC questions were used to calculate a score out of 100 obtaining a severity score per participant. The average severity score was then calculated per anatomical region and body area by taking the severity score for all participants per region/area and dividing it by the number of injuries per region/area. The average OSTRC severity score was subsequently calculated per region/area across all periods.

Risk factor analysis for unique RRIs was completed by using Mixed Effect Logistic Regression models. The severity score was used to determine for which entries the participants had to modify their training. We then classified all entries into two categories: injury (modified training) and no injury (no training modification). Mixed-effects regression models were used to consider the repeated measures of the participants' replies every two weeks, while all other variables were fixed. Significant factors ($p<0.05$) from the univariate analysis were further explored in a multivariate model. Odds ratios (PR; 95% CIs) were reported, and a significance level of $p<0.05$ was accepted.

3. RESULTS

3.1. Response rate

We observed a mean participant response rate of 67.4% (95% CI: 59.81-74.93) over 15 time periods. The lowest response rate was recorded in period 15 (37.5%) and the highest response in period 1 (100%).

3.2. Running exposure

Considering all forms of running per two-week period the mean frequency of running sessions was 6.5 (95% CI 6.0-7.0) and trail running sessions contributed a mean of 2.6 (95% CI 2.3-3.0) to this total. On average participants ran distances of 70.2 km (95% CI 62.8-77.7) and running duration was calculated at an average of 6.5 (95% CI 5.8-7.1) hours.

Table 2: The participants' (n=152) mean (95% CI) running exposure (frequency, distance, and duration of running) over 15 (two-week) periods

	All participants (n=152)	Female (n=32)	Male (n=120)	p-value
Frequency (running sessions / two-week period) mean (95% CI)	6.5 (6.0-7.0)	6.4 (5.3-7.6)	6.5 (5.9-7.1)	0.7439
Distance (km / two-week period) mean (95% CI)	70.2 (62.8-77.7)	59.1 (45.7-72.5)	73.2 (64.5-81.9)	0.1751
Duration (h / two-week period) mean (95% CI)	6.5 (5.8-7.1)	5.8 (4.7-6.9)	6.7 (5.9-7.4)	0.4190

p-value: male vs female study participants; CI: confidence interval.

3.3. Running-related injuries (prevalence, injury rate, severity, anatomical region, body area and tissue type/pathology type)

A total of 205 RRIs were recorded among the 152 participants. Of the 1,536 questionnaire responses over the 30-week study period, 185 (12.0%) questionnaire responses reported one RRI, 7 (0.5%) reported two RRI's and 2 (0.1%) reported three RRI's. A total of 102 (67.1%) participants sustained at least one injury.

Table 3: 1) Total number (n) of questionnaire responses that reported an RRI (gradual- and sudden onset, new- and recurring), 2) prevalence (%), and 3) injury rate (RRIs per 1000 hours)

	RRI	All	Gradual onset	Sudden onset	p-value
All RRIs	Number of questionnaire responses that reported an RRI (n)	194	94	100	
	Prevalence Mean (95% CI)	12.3 (10.2-14.4)	5.9 (4.6-7.1)	6.4 (4.9-8.0)	0.4212
	Injury rate Mean RRIs per 1000h	19.6	-	10.1	
New RRIs	Number of questionnaire responses that reported an RRI (n)	152	67	85	
	Prevalence Mean (95% CI)	9.7 (7.3-12.0)	4.2 (3.0-5.4)	5.5 (3.9-7.0)	0.0917
	Injury rate Mean RRIs per 1000h (95% CI)	15.3	-	8.6	
Recurrent RRIs	Number of RRIs registered (n)	42	27	15	
	Prevalence Mean (95% CI)	2.6 (1.9-3.4)	1.7 (0.9-2.4)	1.0 (0.6-1.4)	0.0918
	Injury rate Mean RRIs per 1000h (95% CI)	4.5	-	2.0	

RRI: Running related injuries; CI: Confidence interval.

3.3.1. Prevalence of RRIs

The mean prevalence of all RRIs measured every two weeks was 12.3% (95% CI: 10.2-14.4). Males had a higher mean prevalence of RRIs 10.5% (95%: 8.6-12.4) than females 1.8% (95% CI: 1.1-2.6), with a mean difference of 8.7% ($p<0.0001$). The mean prevalence of all RRIs was not significantly higher for sudden onset (6.4%; 95% CI: 4.9-8.0) compared to gradual onset RRIs (5.9%; 95% CI: 4.6-7.1), with a mean difference of 0.5% ($p=0.4212$).

3.3.2. Injury rate

The injury rate for new RRIs was 15.3 RRIs per 1000h of running. Males presented with a significantly higher injury rate (12.7 RRIs per 1000h of running) than females (3.1 RRIs per 1000h of running), with an injury rate difference of 9.6 RRIs per 1000h of running ($p=0.0298$).

3.3.3. Anatomical region and body area

In Table 4, the RRI frequencies (n; %) of all RRIs are presented in categories of the main anatomical region and specific anatomical sites for RRIs. The average OSTRC injury severity score is further presented for the injured anatomical regions and body areas.

Table 4: Anatomical region and specific body area of all RRIs (n=205) among 152 trail runners (% all RRIs and OSTRC injury severity score)

Anatomical region	Body area	n	% Of all RRIs (n=205)	OSTRC severity score (mean 95% CI)
Head, neck & face	All	4	2.0	-
	Head /face	2	1.0	-
	Neck	2	1.0	-
Upper limb	All	2	1.0	-
	Shoulder	1	0.5	-
	Wrist	1	0.5	-
Thoracic spine / chest	All	7	3.4	62.6 (52.6-72.5)
	Thoracic spine	4	2.0	-
	Chest / ribs	3	1.5	-
Lower back / abdomen	All	10	4.9	55.5 (41.6-69.4)
	Lumbar spine	8	3.9	56.0 (38.8-73.3)
	Abdomen	2	1.0	-
Hip / groin / pelvis	All	12	5.9	46.4 (34.8-58.0)
	Pelvis / gluteal	6	2.9	47.5 (30.8-64.2)
	Hip / groin	6	2.9	45.3 (27.7-62.9)
Lower limb	All	170	82.9	47.8 (44.47-51.2)
	Thigh (posterior)	13	6.3	38.6 (26.3-51.0)
	Thigh (anterior)	4	2.0	-
	Knee	61	29.8	50.0 (44.7-55.3)
	Shin / lower leg	37	18.0	44.1 (38.0-50.2)
	Ankle	27	13.2	50.0 (41.6-58.4)
	Foot / toes	28	13.7	50.5 (40.4-60.71)

RRI: Running related injuries; CI: Confidence interval.

The main anatomical region affected by RRIs was the lower limb (82.9%), followed by the hip/groin/pelvis (5.9%) and the lower back/abdomen (4.9%). The top three body regions in the lower limb region involved the knee (29.8%), followed by the shin/lower leg (18.0%) and the foot/toes (13.7%).

The highest OSTRC injury severity score was reported for RRIs to the thoracic spine/chest (62.6), followed by lower back/abdomen (55.5) and lower limb (47.8).

The majority of tissue types involved in RRIs were muscle/tendon (52.7%), of which the main pathology type were tendinopathies (27.8%), followed by muscle injuries (20.5%) and joint sprains (8.8%) (online supplementary file 3).

3.4. Risk factors associated with RRIs among trail runners

3.4.1. Risk factors associated with RRIs (Univariate analysis)

Risk factors potentially associated with all RRIs were investigated under the following categories: the demographic profile, running experience, training characteristics, RRI history, and medical history (Table 5).

Table 5: The odds ratio estimate (%; 95%CI) and p-value for trail runners race entrants with an RRI by demographic profile, running experience, training characteristics, RRI history, and medical history (univariate analysis)

Characteristic		Odds Ratio Estimate	95% CI	p-value
Demographic profile				
Age (years)		0.9830	0.9627-1.0030	0.1015
Sex (male/female)		1.2320	0.7736-2.0260	0.3898
BMI (kg/m^2)		0.9712	0.9054-1.0410	0.4057
Running experience (years of running)				
All running		1.0510	0.9719-1.1340	0.2003
Trail running		1.0290	0.9369-1.1260	0.5425
Training characteristics				
Surface mostly ran on	Trails	1.1090	0.7429-1.6830	0.6169
	Road	1.1060	0.8381-1.4950	0.4895
	Grass	0.9314	0.7153-1.2060	0.5889
	Tartan	0.6942	0.3275-1.2720	0.2785
	Treadmill	0.8926	0.6326-1.2260	0.4947
Number (n) of running sessions per two-week time period	Any	0.9006	0.8512-0.9493	0.0002*
	Trail	0.9481	0.8765-1.0190	0.1649
Total running distance (km) per two-week time period		0.9956	0.9919-0.9990	0.0156*
Total ascent (m) per two-week time period		1.0000	0.9999-1.0000	0.9524
Total descent (m) per two-week time period		1.0000	0.9999-1.0000	0.8270
Type of cross-training	Cycling	1.053	0.9952-1.1090	0.0575
	Weight training	0.9780	0.8971-1.0590	0.5969
	Swimming	1.0770	0.8968-1.2590	0.3767
	Rowing	1.1170	0.7737-1.5000	0.4986
	Functional training	0.9565	0.8352-1.0660	0.4689
	Pilates	0.6901	0.4216-0.9462	0.0650
	Other	0.9208	0.7821-1.0280	0.2295
	None	0.9264	0.5209-1.3150	0.7305
RRI history				
Previous RRI (past 12 months)		2.1110	1.3400-3.4910	0.0020*
Current RRI		1.4460	1.0010-2.1360	0.0534
Medical history				
Chronic disease		1.9680	1.1390-3.6440	0.0210*

* Statistically significant.

In the training characteristics category, a higher number of any running sessions (OR=0.9006; p=0.0002) and total running distance (OR=0.9956; p=0.0156) were associated with significantly lower odds of sustaining an RRI among trail runners.

A significantly higher odds of sustaining an RRI was noted among trail runners with a history of a previous RRI in the past 12 months (OR=2.1110; p=0.0020) and among those reporting a chronic disease (OR=1.9680; p=0.0210).

3.4.2. Independent risk factors associated with RRIs (Multiple regression analysis)

In Table 6, the independent risk factors associated with RRIs among trail runners are reported.

Table 6: Independent risk factors associated with RRIs among trail runners (multiple regression analysis)

Characteristic		Odds Ratio Estimate	95% CI	p-value
Training characteristics				
Number (n) of running sessions per two-week time period	Any	0.8889	0.8203-0.9634	0.0041*
Total running distance (km) per two-week time period		1.0010	0.9959-1.0060	0.6991
RRI history				
Previous RRI (past 12 months)		2.0880	1.2790-3.4100	0.0032*
Medical history				
Chronic disease		2.0390	1.1250-3.6960	0.0188*

* Statistically significant.

Independent risk factors associated with RRIs among trail runners included a history of previous RRIs in the past 12 months (OR=2.0880; p=0.0032) and having a chronic disease (OR=2.0390; p=0.0188). A higher biweekly number of running sessions was associated with significantly lower odds of sustaining an RRI among trail runners (OR=0.8889; p=0.0041).

4. DISCUSSION

The main goal of our study was to determine the incidence, prevalence, and clinical characteristics of RRIs among South African trail runners. To our knowledge, this is the first study to investigate injury risk factors among trail runners based on data collected in a prospective cohort study.

4.1. Injury rate and prevalence of RRIs

We reported an injury rate of 19.6 RRIs per 1000 hours of running, with a biweekly RRI prevalence of 12.3% among South African trail runners. In a prospective cohort study among Dutch trail runners followed over six months, Hespanhol et al. reported a lower injury rate of 10.7 RRIs per 1000 hours of running with a higher biweekly RRI prevalence (22.4%).[4] We further reported a statistically significant higher injury rate in males (12.7 RRIs per 1000h of running) compared to females (3.1 RRIs per 1000h of running). This is in contrast to a recent systematic review with meta-analysis and meta-regression that reported no difference in injury rates in all running formats for males compared to females.[21] The small number of female participants in our study affected the reliability of our finding. Future trail running studies should specifically investigate sex differences in injury outcomes using larger sample sizes for females. Hespanhol et al. reported a fourfold higher prevalence for overuse (17.7%) vs acute (4.1%) RRIs.[4] We showed no statistically significant difference in prevalence for sudden onset (6.4%) vs gradual onset (5.9%) injuries (p=0.4212). We had a higher number of injured runners at baseline (53.8%) compared to Hespanhol et al. (18.0%).[4] This may explain the differences in injury rate and prevalence, as a history of previous injury increases the risk for further injury in runners.[22]

4.2. Anatomical region and body area of RRIs

In our study, the lower limb was the most common anatomical region of RRIs among trail runners (82.9%). This is supported by the findings of a systematic review[5] and a prospective cohort study[4] on injury epidemiology among trail runners. The most common body areas involved were the knee (29.8%), shin/lower leg (18.0%) and foot/toes (13.7%). This was in line with findings among Dutch trail runners where lower leg (20.3%), knee (18.2%), and foot (14.8%) were the most commonly reported RRIs. Even though a recent systematic review[5] showed similar results, Viljoen et al. mainly included race participation studies where data were collected cross-sectionally, complicating comparison to our current findings. The slight variation between studies on the top three most reported injured body areas could be due to various running environments and slope gradients resulting in different loading patterns, specifically the lower limb.[23] The increased pressure on the lower limbs during running could explain the higher frequency of lower limb injury, not only among trail runners but also in orienteers, triathletes and road runners.[24] These findings highlight the importance of developing future RRI prevention strategies focused on managing the risk for lower limb RRIs.

4.3. Independent risk factors

Similar to previous studies investigating injury risk factors among road runners[25] and elite athletes,[26] we showed that a history of previous RRI is an independent risk factor for injury among trail runners. Trail running literature investigating injury risk factors did not specifically investigate injury history as a possible injury risk factor.[8 27] It seems as if some runners are more injury prone and explanations are still lacking. A possible reason may be that kinematic and motor control deficits exist following injury,[28] with subsequent higher risk of re-injury while running on uneven, changing surfaces. This finding emphasises the need for rehabilitation through tissue loading among injured trail runners to obtain optimal physiological, neural, and structural tissue adaptation[29] before a full return to trail running participation.

Chronic diseases such as hypercholesteremia, hypertension, asthma, hypothyroidism, and diabetes were associated with an increased risk for sustaining an RRI in our study. Previous studies have reported an association between chronic disease and gradual onset injury.[30] Certain medications treating chronic diseases have also been associated with an increased risk for injury. These include tendon ruptures following corticosteroid use,[31] statin-induced tendinopathies,[32] and enthesopathies following use of fluoroquinolones.[33] These findings should be interpreted with caution. It is beyond the scope of this study to determine whether the increased risk for sustaining an RRI noted was due to the presence of physiological stressors of the disease or the medication used to treat the specific disease. Future studies need to explore the casual nature of chronic disease as an injury risk factor before appropriate injury prevention recommendations can be formulated.

A higher biweekly number of running sessions was associated with lower odds for RRIs in our study but care should be taken in interpreting this finding. We defined injury as training modification. Therefore, it is reasonable to expect that injured runners in our study have less running exposure compared to healthy runners with no training modification, as a result of the injury definition we used.

To understand injury risk, the non-linearity of risk factors should be considered to allow for the impromptu interaction between risk factors over time.[34] Known risk factors in trail running are limited, and no studies account for the complexity of RRIs in this population. Therefore, medical professionals should be mindful of the interaction between risk factors while using

them in combination with their clinical knowledge to design injury prevention strategies for trail runners.

4.4. Limitations

In South Africa, most trail running races are not affiliated with Athletics South Africa, and runners can participate without membership to any trail running governing body. Without a reference for the population size, we used a convenience sample and could not determine whether our sample was representative of the South African trail running population. This study specifically studied South African trail runners exposed to environments unique to the geography of South Africa, and care should be taken in generalising our results to the global trail running community. We used self-reported RRI data; thus, the findings of tissue and pathology types involved in RRIs should be interpreted with caution. We investigated specific injury risk factors such as biweekly elevation changes and running exposure, where the accuracy of self-reported data could have been influenced by recall bias. Gradual onset injuries could have originated from other sporting activities (cycling, weight training, etc.) and may not be purely running-related. We also acknowledge that sudden onset injuries could have been due to underlying repetitive tissue overload with subsequent acute symptoms. To investigate runners with the intent to run on trails, our inclusion criteria required a runner to train towards a trail run race of at least 21km or more. However, we acknowledge that certain runners may still perform the largest portion of their training on non-trail surfaces. Limited by our sample size, we could only explore a certain amount of injury risk factors. The methodology used in our study did not allow us to account for the complexity of sports-related injuries. Future studies using larger sample sizes, may use a time-to-event analysis to explore varying running exposures such as spikes in running distance.

5. CONCLUSION

Approximately two out of three trail runners sustain an RRI mainly affecting the knee, shin/lower leg, and foot/toes. We report an overall injury rate of 19.4 RRIs per 1000h of running (males: 12.7 RRIs per 1000h of running; females: 3.1 RRIs per 1000h of running) with a higher injury rate, and prevalence noted for sudden vs gradual onset RRIs. A history of previous RRI in the past 12 months and having a chronic disease were independent risk factors for sustaining an RRI among trail runners. Before our findings are implemented into injury

prevention strategies, further research is needed to determine if these risk factors are associated with injury in other trail running populations.

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CHAPTER 4

Independent Risk Factors Predicting Gradual Onset Injury in 2824 Trail Running Race Entrants: SAFER XVIII study

Published as:

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 Environ Med. 2021 Sep;32(3):293-301. doi: 10.1016/j.wem.2021.04.002. Epub 2021 Jul 12.

PUBLICATION DETAILS

Title of publication:

Independent Risk Factors Predicting Gradual Onset Injury in 2824 Trail Running Race Entrants: SAFER XVIII study

Journal (ISSN):	**Impact factor (2020):**	**Date published:**
Wilderness and Environmental Medicine (1080-6032)	1.518	12 July 2021

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CONFRERENCE PRESENTATION DETAILS

Title:

Over 14% trail runners report an overuse injury in a 12-month period, mostly affecting the knee and anterior thigh: A SAFER study in 2824 race entrants

Conference:

SASMA Congress

Location:

Cape Town, South Africa

Date:

10-13 October 2019

Type of presentation:

Platform

ABSTRACT

Introduction: Trail running is characterized by elevation changes with uneven and varying running surfaces. Risk factors that may predict gradual onset running related injuries (GORRIs) in short distance trail running have not been explored. The objective was to determine risk factors that predict GORRIs in trail running race entrants who entered for mass community-based trail running events.

Methods: In this descriptive cross-sectional study, data were collected prospectively from a prerace medical screening questionnaire over 4 trail run events held annually. Using a Poisson regression model, runner demographics, race distance, running training/racing variables, history of chronic diseases (number of chronic diseases reported as a cumulative "chronic disease composite score"), and allergies were investigated to determine factors predicting self-reported GORRI history in the previous 12 mo.

Results: This study included 2824 race entrants (80% of entrants). The retrospective annual incidence for GORRIs was 13%. Independent risk factors predicting GORRIs were: longer race distance (P<0.0001), increasing chronic disease composite score (P=0.0012), and a history of allergies (P=0.0056). The lower limb (94%) was the main anatomical region of GORRIs, and soft tissue injuries accounted for most (83%) GORRIs. Common specific GORRIs were iliotibial band syndrome (22%), achilles tendon injury (10%), and hamstring injury (9%).

Conclusion: Independent risk factors predicting GORRIs among trail running entrants included longer race distance, a higher chronic disease composite score, and a history of allergies. This study has highlighted trail running race entrants at risk for sustaining GORRIs that could be targeted for future injury prevention interventions.

Keywords: chronic disease, running related injuries, incidence, epidemiology, off-road running, prerace medical screening

1. INTRODUCTION

Physical activity is associated with a reduced risk for developing chronic disease and premature all-cause mortality.[1] Evidence further suggests that participating in outdoor physical activity improves mental wellbeing.[2] Trail running involves running on off-road terrains in outdoor environments and is characterized by large elevation changes.[3] Even though running has numerous proven physical and mental health benefits, it is still associated with a high risk for injury.[4]

The most common injuries described in running literature involve gradual onset running related injuries (GORRIs)[4 5] as a result of low kinetic energy transfer over time causing tissue damage.[6] Most studies only focus on marathon and ultramarathon running distances[7-14] with limited information on GORRIs among trail runners participating in shorter distance trail run events.

In one study among ultra-distance trail runners, injury risk factors among elite runners included being more experienced runners, and runners with physical labor occupations.[13] However, the authors did not investigate the medical history of participants.[13] The prevalence of certain chronic diseases among endurance runners is up to 13%,[15] and chronic diseases are also associated with an increased risk for gradual onset injuries.[16-20] Additionally, some medication used in the treatment of chronic diseases are associated with an increased risk for injury.[21-27] The relationship between chronic diseases and risk of GORRIs has not been explored in trail runners.

The importance of investigating injury profiles and determining associated injury risk factors for GORRIs among this population is emphasized by the challenges faced during medical coverage at some trail running events.[28] These events can span over large geographical regions in remote settings where medical staff and runners are exposed to environmental hazards which include extreme weather, water crossings, insect-borne infections, and wildlife.[28 29] In these settings, injured runners often receive delayed medical care due to the logistical challenges of providing emergency medical care in remote regions.[28 29] A history of previous injury is a known injury risk factor among runners,[30 31] therefore an attempt should be made to prevent injury in training period prior to race participation. For specific injury prevention strategies among short distance trail runners in the training period prior to race participation, we need an improved understanding of the injury profiles and associated injury risk factors for GORRIs in this population.

The main aim of this study was to determine risk factors that predict a history of GORRIs in trail running race entrants who entered for mass community-based trail running events. A secondary aim was to report the epidemiology and clinical characteristics of self-reported GORRIs among trail running race entrants.

2. METHODS

2.1. Study Design

A descriptive cross-sectional analysis of data collected prospectively at 4 annual trail running events.

2.2. Participants and data collection

The research ethics committee of the University of Cape Town (REC 009/2011 and REC 030/2013) approved the protocol and the research ethics committee of the University of Pretoria (REC 433/2015) approved the on-going data collection and subsequent analysis of the data.

This study forms part of the strategies to reduce adverse medical events for the exerciser (SAFER) studies - SAFER XVIII. Participants for this study were race entrants from the Two Oceans trail runs, a mass community-based trail running event in South Africa that is comprised of a 10 km and a 22 km race. No qualification was required for either of the events. Entrants were defined as any runner registering for the races (registration typically opens 3-5 mo before the races) held annually over 4 y (2012-2015).

2.3. Online prerace medical screening

In this 4 y study period a compulsory prerace medical screening questionnaire was implemented for all race entrants. The prerace medical screening questionnaire was based on the European Association for Cardiovascular Prevention and Rehabilitation (EACPR) recommendations[32] and consisted of the following main categories: history of cardiovascular disease (CVD), symptoms of CVD, risk factors for CVD, other chronic diseases, general prescription medication use, medication use during racing, injury and a past history of collapse during racing. The full detail of this online medical screening and implementation thereof has

been described in previous studies.[15 33] Entrants completing the screening were given the opportunity to consent to their data being used for research purposes.

In the prerace medical screening, entrants were asked the following specific question related to gradual onset injuries: "*Do you or did you suffer from any symptoms of a chronic (no accident) running injury (muscles, tendons, bones, ligaments or joints) in the past 12 months or currently?*". We defined these injuries as "GORRIs", as recommended by the 2020 international Olympic committee (IOC) consensus statement.[6] For inclusion, an injury was defined as "*An injury that is/was severe enough to interfere with running or require treatment e.g. use medication or require you to seek medical advice from a health professional*". If the response to the previous question was "yes", entrants were required to complete additional questions related to the gradual onset running injury, including: past or current injury, anatomical region, body area, type of anatomical structure, severity and whether the injury was one of the more commonly known GORRIs.

2.4. Primary Outcome

The primary outcome of this study was a history of GORRIs in the past 12 mo among trail running race entrants. The following three categories of independent variables of interest as factors predicting GORRIs were explored: 1) demographics (sex and age groups) and race distance, 2) running training/racing variables (years as a recreational runner, average weekly training/running frequency in the last 12 mo, average weekly training/running distance in the last 12 mo, average training speed, race vs average training speed ratio), and 3) history of chronic disease (any risk factors for CVD, history of existing CVD, symptoms of CVD, endocrine disease, respiratory disease, gastrointestinal disease, nervous system/psychiatric disease, kidney/bladder disease, hematological/immune system disease, and cancer), and any allergies. We calculated a further variable, a chronic disease composite score (out of 10), which is a continuous variable of the sum of an individual's answer to 10 questions related to a history of chronic disease (any risk factors for CVD, history of existing CVD, symptoms of CVD, endocrine disease, respiratory disease, gastrointestinal disease, nervous system/psychiatric disease, kidney/bladder disease, hematological/immune system disease, and cancer).

In the reporting on the outcomes in this manuscript, we used the terminology "prediction" instead of "association", based on recently published guidelines regarding clear goal setting in sports injury research.[34]

In addition, we also reported the retrospective annual incidence (% runners: 95% CI) and frequency of injury characteristics (% of injuries) for anatomical region, body area, tissue type and common specific GORRIs. Injury severity was recorded as frequencies (%) of less severe (Grade I – only experience symptoms after exercise; and Grade II – experience symptoms during exercise but it does not interfere with exercise) and more severe (Grade III – experience symptoms during exercise that may interfere with training/competition; and Grade IV – may not be able to train/compete due to pain) injuries.[35] More severe injuries were classified as those that interfered with the runner's ability to continue with training or racing.

2.5. Statistical Analysis

All race entrants' data were entered into Excel and then transferred into SPSS statistical software (version 25) and SAS (V.9.4) statistical analysis system. The binary-scaled dependent variable in the model was the response to the question related to GORRI, and entrants were coded as having a GORRI if they reported 1) a GORRI in the past 12 mo or 2) a current GORRI. Entrants could report more than one injury. Frequency analysis was performed for the descriptive data (% of all entrants; 95%CIs). For the risk factors, two groups were used (injured group n=338, control group n=2486), a Poisson distribution with a log link function was used and the *P*-values for a Type 3 GEE analysis were reported. All possible factors were first explored in a univariate analysis. Using highly significant factors ($P<0.001$, due to the small sample size) from the univariate model, a multiple regression model was performed. Prevalence ratios (PR; 95% CIs) were reported and a final significance level of <0.05 was accepted.

3. RESULTS

Over the 4 annual events, 3547 runners entered and 2824 entrants (80%) gave consent for their data to be analyzed (10 km [n=1131] and 22 km [n=1693]). There were no significant differences between entrants consenting as study participants compared to all race entrants by sex, age groups or race distance (Table 1).

Table 1: Characteristics of all trail run race entrants and consenting entrants

Characteristics		All trail run entrants (n=3547)	Entrants consenting as study participants (n=2824)	*P*-value[b]
		%[a] (n)	%[a] (n)	
Sex	Males	57 (2003)	57 (1597)	0.9485
	Females	44 (1544)	43 (1227)	
Age groups	≤30 y	30 (1073)	30 (857)	0.9124
	31 to 40 y	37 (1312)	36 (1022)	
	41 to 50 y	23 (816)	24 (666)	
	>50 y	10 (346)	10 (279)	
Race distance	10 km	41 (1463)	40 (1131)	0.3342
	22 km	59 (2084)	60 (1693)	

[a] Percentage of the total
[b] *P*-value - all trail run entrants vs. entrants consenting as study participants

3.1. Annual incidence of GORRIs

In the previous 12 mo, 338 trail running race entrants reported a total of 349 GORRIs. Eleven (3%) of the 338 participants reported a second injury (total injuries, n=349) and 82 (24%) of the 338 participants suffered from a "current" injury at the time of completing the prerace screening questionnaire at race registration. The retrospective annual incidence of injuries in this study population was 13% (95%CI: 11 – 14).

3.2. Characteristics of GORRIs among trail running race entrants

The main anatomical region affected by GORRIs was the lower limb (94%: n=328), followed by the trunk (5%: n=16) and the upper limb (1%: n=2). The most common body areas affected by GORRIs were the knee (35%: n=123), followed by the shin/lower leg/calf (16%: n=55) and the thigh (11%: n=38) (Table 2).

Table 2: Anatomical region and specific body area of GORRIs among trail running race entrants (% gradual onset trail running injuries) (n=349)

Anatomical region	Body area	% (n)
Head and neck	Head	0 (1)
Upper limb	Shoulder	0 (1)
	Wrist	0 (1)
Trunk		5 (16)
Lower limb	Hip/groin/pelvis	5 (18)
	Thigh	11 (38)
	Knee	35 (123)
	Achilles	11 (37)
	Shin/lower leg/calf	16 (55)
	Ankle	6 (21)
	Foot	10 (36)
Unspecified		1 (2)
Total		100 (349)

The most common specific GORRI was iliotibial band syndrome (ITBS) (22%: n=78), followed by achilles tendon injury (10%: n=35), hamstring injury (9%: n=30), calf muscle injury 7%: n=23) and foot/heel pain (5%: n=19) (Table 3).

Table 3: The frequency of common specific GORRIs (12 mo prior to race entry) among trail running race entrants (% gradual onset injuries) (n=349)

Common specific GORRIs[a]	% (n)
Knee - iliotibial band syndrome (ITBS)	22 (78)
Achilles tendon injury	10 (35)
Hamstring injury	9 (30)
Calf muscle injury	7 (23)
Foot or heel pain	5 (19)
Anterior knee pain (AKP) / patellofemoral pain (PFP)	5 (16)
Lower back pain (LBP)	4 (15)
Plantar fasciitis	4 (14)
Hip muscle injury (including gluteus / buttock muscles)	3 (12)
Shin splints (muscle/tendon)	3 (10)
Shin splints (bone)	2 (8)
Quadriceps muscle injury	1 (3)
Lower leg compartment syndrome	1 (2)
Other	24 (84)
Total	100 (349)

[a] Gradual onset running related injuries

The frequency of Grade IV injuries (not able to train or compete due to injury) was 18% (n=63). The frequency of Grade III injuries was 33% (n=114), followed by Grade II (26%: n=90) and Grade I (23%: n=79). Slightly more severe GORRIs were reported as 51% (n=177) compared to the less severe injuries (48%: n=169).

3.3. Risk factors predicting a history of gradual onset injuries in trail running race entrants (Univariate analysis)

3.3.1. Runner demographics (sex, age group) and race distance

The overall prevalence of GORRIs (n=338) among trail running race entrants was 12% (95%CI: 11-14). The prevalence of GORRIs was not significantly different between males and females (PR=1.0, *P*=0.7722) and across age groups (*P*=0.1246). There was a higher prevalence of GORRIs among trail running race entrants participating in the longer race distance (PR=1.8, *P*<0.0001) (Table 4).

Table 4: The number (n), prevalence (%; 95%CI) and prevalence ratio (PR) (95%CI) of trail running race entrants with a history of GORRI by race distance, sex, and age group

Characteristics		Consenting trail run race entrants (n=2824)	Trail run race entrants with a GORRI[a] (n=338)		PR[b] (95% CI)	*P*-value
		n	n	Prevalence (%; (95% CI)		
Overall		2824	338	13 (11-14)		
Runner demographics						
Sex	Males	1568	184	12 (10-14)	1.0 (0.8-1.3)	0.7722
	Females	1210	154	12 (11-14)		
Age groups	≤30 y	840	86	10 (8-13)		0.1246
	31 to 40 y	1002	128	13 (11-15)	1.3 (1.0-1.7)	
	41 to 50 y	663	92	14 (11-17)	1.4 (1.0-1.8)	
	>50 y	273	32	11 (8-16)	1.1 (0.7-1.6)	
Race distance						
	10 km	1113	93	8 (7-10)	1.8 (1.4-2.3)	<0.0001*
	22 km	1665	245	15 (13-17)		

[a] Gradual onset running related injuries
[b] Prevalence ratio
*Statistically significant
Missing data in 46 entrants

3.3.2. Running training/racing history

The number of years of recreational running (PR=1.1 per 5-unit increase; *P*=0.0014) and an increased average weekly training/running distance in the last 12 mo (PR=1.0 per 5-unit increase; *P*=0.0061) were associated with an increased PR for GORRIs (Table 5).

Table 5: The prevalence (% and 95%CI) and prevalence ratio (PR; with 95%CI) of trail running race entrants with a GORRI by training/racing history (unadjusted)

Running training/racing history	Points in the continuous variable[a]	Trail run race entrants with a GORRI[b] (n=338) Prevalence (%; 95% CI)	PR[c] (95% CI)	*P*-value
Number of years as a recreational runner	3 y 6 y 13 y	11 (9-12) 11 (10-13) 13 (12-14)	5-unit increase 1.1 (1.0-1.2)	0.0014*
Average weekly training/ running frequency in the last 12 mo (times per week)	2 3 4	11 (9-13) 12 (11-13) 13 (11-14)	2-unit increase 1.1 (1.0-1.3)	0.0610
Average weekly training/running distance in the last 12 mo	15 km 25 km 40 km	11 (10-12) 12 (11-13) 13 (12-15)	5-unit increase 1.0 (1.0-1.1)	0.0061*
Average training speed	9 km/h 11 km/h 13 km/h	12 (10-13) 12 (11-14) 13 (11-14)	1-unit increase 1.0 (1.0-1.1)	0.5046
Race vs training speed ratio (RS/TS[d])	0.5 1.0 1.5	14 (12-17) 11 (9-13) 8 (5-13)	0.5-unit increase 1.0 (0.9-1.1)	0.0590

[a] Points on the continuous variables
[b] Gradual onset running related injuries
[c] Prevalence ratio
[d] Race speed (km/hr) vs training speed (km/hr) ratio = race speed/training speed; a value >1 is a faster average race speed compared to average training speed, and a value <1 is a slower average race speed compared to average training speed
*Statistically significant

3.3.3. History of chronic disease and allergies

The results of trail running race entrants with a GORRI by history of chronic disease and allergies is shown in Table 6.

Table 6: The number (n), prevalence (%; 95%CI) and prevalence ratio (PR; with 95%CI) of trail running race entrants with a GORRI by history of chronic disease and allergies (unadjusted)

Characteristics		Consenting race entrants (n=2824)	Race entrants with a GORRI[a] (n=338)		PR[b] (95% CI)	*P*-value
		n	n	Prevalence (%; 95% CI)		
History of chronic disease						
Chronic disease composite score (0-10)[c]	0	-	-	11 (10-12)	2-unit increase 1.7 (1.4-2.2)	0.0004*
	2	-	-	19 (15-23)		
	4	-	-	32 (21-49)		
History of allergies						
Any allergies	yes	322	65	19 (15-24)	1.7 (1.3-2.2)	0.0008*
	no	2455	273	11 (10-13)		
	missing	47	0			

[a] Gradual onset running related injuries
[b] Prevalence ratio
[c] The composite number of 10 chronic diseases for an individual (continuous variable, therefore, no number of participants in the groups)
*Statistically significant

A higher chronic disease composite score was associated with a higher prevalence of GORRIs among trail running race entrants (PR=1.7; *P*=0.0004) in a "dose-dependent" fashion (Figure 1). For every two additional chronic diseases, the prevalence of GORRIs increased 1.7 times. Notably, the confidence intervals widened as the score increased, due to the number of entrants with higher composite scores decreasing. A history of any allergies (PR=1.7, *P*=0.0008) was associated with a higher PR for GORRIs among trail running race entrants.

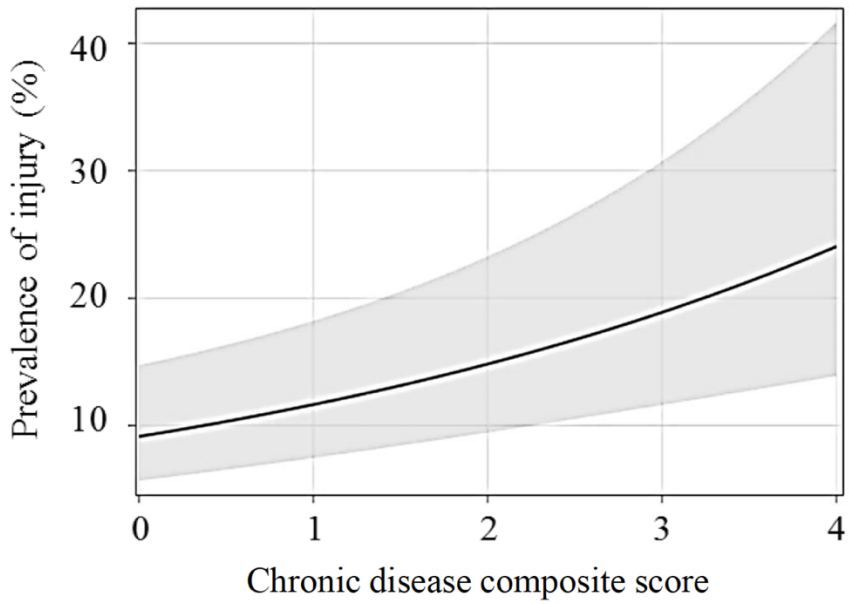

Figure 1: The relationship between the prevalence of GORRIs and the number of chronic diseases (chronic disease composite score) (shaded area is 95% CI).
Wide confidence intervals are indicative of the small sample size at that score

3.4. Independent risk factors predicting a history of GORRIs in trail running race entrants (Multiple Regression Analysis)

Independent risk factors predicting a history of GORRIs in trail running entrants were longer race distance (PR=1.9, *P*<0.0001), a higher chronic disease composite score (PR=1.6, *P*=0.0012), and a history of any allergies (PR=1.6, *P*=0.0056) (Table 7).

Table 7: Independent risk factors that predict a history of GORRIs in the past 12 mo (multiple regression analysis)

		Runners with a GORRI[a] % (95% CI)	PR[b] (95% CI)	*P*-value
Race distance				
Race distance	10 km 22 km	9 (7-11) 17 (15-20)	1.9 (1.5-2.4)	<0.0001*
History of chronic disease				
Chronic disease composite score[c]	0 2 4	12 (10-14) 19 (15-23) 30 (20-46)	2-unit increase: 1.6 (1.3-2.1)	0.0012*
History of allergies				
Any allergies	Yes No	18 (14-22) 11 (10-13)	1.6 (1.2-2.0)	0.0056*

Adjusted for age and sex
[a] Gradual onset running related injuries
[b] Prevalence ratio
[c] The composite number of 10 chronic diseases for an individual (continuous variable)
*Statistically significant

4. DISCUSSION

In our study, runners entering for the longer trail run had a higher prevalence of self-reported GORRIs. Runners entering longer race distances are usually more experienced and train at higher weekly running distances in comparison to entrants of shorter race distances. Among Greek trail runners, increased running experience was associated with a higher risk of injury.[13] We found similar results in our univariate analysis indicating that increased years of running were associated with a higher PR of a GORRI. Our univariate analysis also indicated that an increased average weekly running distance was associated with a higher prevalence of a GORRI. Future studies using larger sample sizes may identify running experience and weekly running distance as independent risk factors predicting a history of GORRIs.

We showed that a higher chronic disease composite score predicted a history of GORRIs. Specifically, for every two additional chronic diseases present the prevalence of GORRIs increased 1.6 times in a "dose-dependent" fashion. This is an intriguing finding. The prevalence of chronic disease among endurance runners has been reported at between 2% to 13% and 16% of runners have at least one risk factor for CVD.[15] Studies confirm that a variety of chronic diseases, which affect various organ systems, are associated with an increased risk for gradual onset injuries.[16-20] For example, diabetes mellitus, hypercholesteremia, and obesity are associated with a higher risk of tendinopathy,[16-18] while chronic obstructive pulmonary disease

(COPD) is associated with an increased risk for bone stress injuries.[19 20] Another consideration is that the medications used in the treatment of chronic diseases may also be associated with an increased risk for injury.[21-27] There are reports that drug-induced tendinopathy is associated with the use of fluoroquinolones,[24] statins,[22 25] corticosteroids,[21] aromatase-inhibitors,[27] and isotretinoin.[23] A higher risk for tendon ruptures[21] and osteoporosis[26] are reported with the use of corticosteroids, while isotretinoin increased the risk for developing enthesopathy.[23] The relationship between the medication dosage and adverse effects is not well quantified in the use of corticosteroids,[26] but the adverse effects of statins appear to be dose-dependent. Finally, certain medication interactions are associated with increased tendon toxicity[36] and combinations of medications are a further risk factor for developing a toxic tendinopathy.[37] The cross-sectional nature of our study limits our ability to establish a cause-effect relationship between the chronic disease composite score and injury risk. These findings do suggest that not only the presence of chronic disease, but also the choice of medication used in treatment, medication dosage, and medication interactions need to be explored as risk factors for GORRIs in future studies.

We also showed that a history of allergies predicted a history of GORRIs. Trail runners participate in various outdoor settings where they are exposed to a variety of potential allergens. Trail running is an endurance sport, and it is well established that a history of allergies is common in endurance athletes.[15 38] We can only speculate on the possible reasons for the association between allergies and GORRI. Again, both the allergy itself and the medication used to treat allergies may be mechanisms responsible for the increased risk of injury. Anti-histamines are commonly used to treat allergies, but have side-effects such as fatigue and drowsiness.[39] If this medication is used during training and racing, acute fatigue can alter lower extremity muscle strength, postural control, and ankle joint position sense, which may increase injury risk.[40] Future research should explore the relationship between allergies, the medication used to treat allergies and GORRIs.

This is the only study to report the annual incidence (13%) of GORRIs among short distance trail running race entrants, therefore we could not compare our results to any current literature. Our results show that the lower limb (94%) is the most commonly injured anatomical region and this is a similar finding to that previously reported among longer distance trail runners.[8 9 11 13 14 41] In our study, the knee was the most common body area for GORRIs (35%) which is much higher compared to Dutch trail runners (18%).[41] In downhill running, the knee is exposed to increased flexion angles during load absorption and redistribution, and this may contribute

to the higher prevalence of knee injuries.[42] The lower frequency of knee injuries reported among Dutch trail runners[41] may be related to a difference in the trail running landscape in the Netherlands with minimal elevation changes.

Our results indicated that soft tissue accounted for 82% of all injured tissue types. The specific tissues involved were muscle (33%), followed by tendon (30%) and ligament (18%), and these findings are similar to those reported in Dutch trail runners (muscle=28%, tendon=24%, ligament=7%).[41] In ultra-distance trail runners similar injured tissue types were found with tendon (36%), ligament (43%), and muscle (21%).[11] However, we note that in the Italian trail running study, acute injuries were included, specifically a high number of ankle sprains. Therefore, we cannot strictly compare our data to that study.[11]

Finally, we show that 51% of GORRIs are severe enough to interfere with training or competition (Grade III and IV). Even though Grade IV injuries were the least frequently reported (18%), it is of concern if a trail runner cannot continue with running due to pain, especially during training/racing in remote regions where medical evacuation is challenging.[28] We cannot compare this finding to other studies because there is substantial variation in the definitions of injury severity in the trail running literature,[41 43] which restricts our ability to compare results.

4.1. Limitations

We acknowledge that this study has several limitations. We cannot determine a cause-effect relationship between any of the identified risk factors due to the cross-sectional nature of the study. All the injury and training data are self-reported and could have been affected by recall bias. Due to recall bias, we could not accurately determine the study participants' actual running exposure on trails. The diagnosis of injuries could not be verified. Lastly, we acknowledge that many other factors (elevation change, running surface, individuals' level of conditioning, intrinsic lower limb biomechanics, footwear etc.) may also be associated with the risk for developing GORRIs, but could not be explored in our study. Future studies are needed to explore the causal relationship between the risk factors and GORRIs among short distance trail running race entrants.

5. CONCLUSION

Independent risk factors that predict a history of GORRIs among short distance trail running entrants include longer race distance, a higher chronic disease composite score, and history of any allergies. Specifically, for every two additional chronic diseases present the prevalence of GORRIs increased by 1.6 times in a “dose-dependent” fashion. Our results highlight trail running race entrants at risk for sustaining GORRIs that could be targeted for future injury prevention interventions.

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CHAPTER 5

Development of a Trail Running Injury Screening Instrument: A multiple Methods Approach

Submitted to:

Physical Therapy in Sport

MANUSCRIPT DETAILS

Title of manuscript:

Development of a Trail Running Injury Screening Instrument: A multiple Methods Approach

Journal (ISSN):	**Impact factor (2020):**	**Date submitted:**
Physical Therapy in Sport (1466-853X)	2.365	26 April 2022

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ABSTRACT

Objective: To develop a trail running injury screening instrument (TRISI) for utilisation as clinical decision aid in determining if a trail runner is at an increased risk for injury.

Design: Multiple methods approach.

Methods: The study utilised five phases 1) identification of injury risk factors 2) determining the relevance of each identified risk factor in a trail running context, 3) creating the content of the Likert scale points from 0 to 4, 4) rescaling the Likert scale points to determine numerical values for the content of each Likert scale point, and 5) determining a weighted score for each injury risk factor that contributes to the overall combined composite score.

Results: Of the 77 identified injury risk factors, 26 were deemed relevant in trail running. The weighted score for each injury risk factor ranged from 2.21 to 5.53 with the highest calculated score being 5.53. The final TRISI includes risk categories of training, running equipment, demographics, previous injury, behavioural, psychological, nutrition, chronic disease, physiological, and biomechanical factors.

Conclusion: The developed TRISI aims to assist the clinician during pre-race injury screening or during a training season to identify meaningful areas to target in designing injury risk management strategies and/or continuous health education.

Keywords: Off-road running, clinical decision aid, risk management, running, injury

1. INTRODUCTION

Trail running is the most popular off-road running discipline.[1] Trail runners are often exposed to significant elevation changes and variable running surfaces in natural environments, such as mountains, forests and deserts.[2] Running has numerous health benefits[3], but trail running also has a high incidence of injury reported for training and race participation.[4]

During training or racing, a trail runner can be exposed to gradual onset injury like tendinopathies[5 6] or sudden onset injury like ankle sprains.[7 8] Trail running is semi- to fully self-sufficient, with runners required to use running packs to carry limited nutritional supplies and safety equipment,[9] while often traversing remote natural environments. In remote regions, medical support is challenging in terms of finding and evacuating injured runners.[10] Although rare, fatal injuries in trail running have been reported following blunt trauma from falling and hypothermia following an injury that resulted in an inability to further run/walk.[11] Little can be done to improve medical access in certain remote regions. Therefore, it is important to identify runners at an increased risk for injury before training or race participation in remote environments. Trail runners also perform regular training in urban regions on asphalt surfaces.[5 8] To allow for consistent training and access to running-related health benefits, clinicians need to consider injury risk management strategies focused on the individual trail runner's risk profile.

Considering the dearth of literature on the epidemiology of trail running injury[4] and associated injury risk factors, clinicians have limited research evidence to guide clinical decision-making regarding injury risk during training or race-participation. Evidence-based medicine (EBM) involves the integration of the best available research evidence in combination with clinical experience and the runner's preferences.[12] In the light of the limited research evidence, clinicians are heavily reliant on clinical experience during clinical decision-making surrounding injury risk management in trail running. With trail running being a relatively newer and smaller sport,[1] few clinicians get regular exposure to injury risk management in trail running. By utilising the knowledge of current experts in injury risk management in trail running, we can assist clinicians in the decision-making process regarding safe trail running participation and point out areas to target during the application of injury risk management strategies.

Currently, no clinical decision aid exists in trail running. Therefore, this study aimed to develop a clinical decision aid for clinicians to screen potentially increased injury risk in trail runners.

The screening clinical decision aid is not aimed at predicting injury, but at identifying areas of increased risk among trail runners.

2. METHODS

Using a multiple methods approach, applying quantitative research methodology, we developed a clinical decision aid to assist clinicians during an injury screening process to determine if a trail runner is at an increased risk for injury. We refer to this clinical decision aid as a trail running injury screening instrument (TRISI). The TRISI is not designed to predict injury among trail runners but to highlight areas of potential clinical interest regarding increased risk of injury. The clinician can use the information derived from the TRISI to design individualised risk management strategies, including health education. The TRISI development process involved five phases as presented in Figure 1.

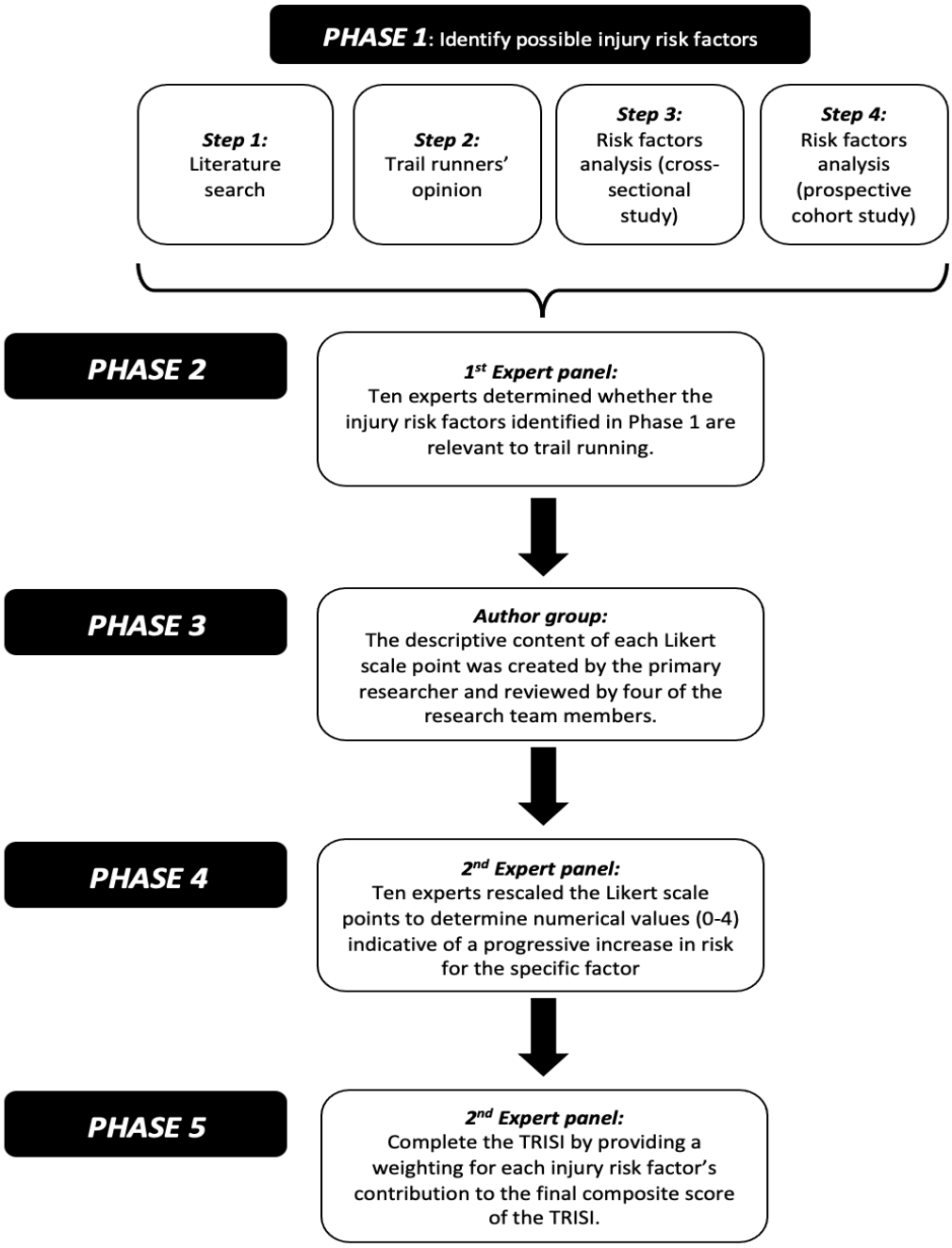

Figure 1: The five phases of the TRISI development

2.1. Phase 1: Identification of possible injury risk factors

A four-step multiple-methods process was used to create a provisional list of potential injury risk factors associated with trail running injury (Figure 1).

2.1.1. Step 1: Literature search

The goal of *Step 1* was to identify a wide variety of described injury risk factors that could be associated with higher injury risk in trail running. We did not consider the quality of evidence of the identified studies. Due to the shortage of literature on trail running injury risk factors, we searched for studies investigating any form of endurance running (road running, cross-country, and any definitions of off-road running[1]). Four electronic databases were searched on EBSCOhost, namely CINAHL, Health Source: Nursing/Academic Edition, MEDLINE, and SPORTDiscus. A date range limiter of 2009 to 2019 was applied to the search. Two sets of keywords were used (run* and injury risk factor*) and combined with the AND operator to obtain the final results. For eligibility, studies had to refer to running-related injury risk factors for training or race participation. We incorporated all study designs, excluding editorials and commentaries. Injury risk factors related to multi-sport disciplines such as triathlons were excluded. Statistically non-significant factors and factors related to track and field athletics participation were excluded. One researcher (CTV) screened the titles and abstracts and extracted data from the eligible full-text articles. Extracted risk factors were added to a provisional injury risk factor list, which included categories of training, equipment, demographic profile, injury history, behavioural factors, psychological factors, nutrition, chronic disease, medication use, and biomechanical variables.

2.1.2. Step 2: Trail runners' opinion

In *Step 2*, we assessed the opinions of trail runners on which factors they felt to be associated with a higher risk of injury. We used data collected via the final follow-up questionnaire in a prospective cohort study investigating the epidemiology of trail running injury and associated risk factors.[8] This questionnaire was sent to all participating trail runners (n=152) and consisted of one open-ended question: "In your opinion, what factors increase your risk for getting injured during trail running (training or racing)?". All responses (n=63) to this question were evaluated and grouped in categories of training factors, demographic profile, injury history, behavioural factors, equipment use, nutrition, and medication use (Table 1). Subsequently, the grouped risk factors categories were added to the provisional injury risk factor list established in *Step 1*.

Table 1: Categories of increased risk for trail running injury reported by South African trail runners

Category	Risk factor	Number of risk factors reported (n=145)	% Of all reported risk factors
Training factors	**All**	**116**	**80.0**
	Lack of strength / strength / cross / agility / balance training	27	18.6
	Lack of recovery / fatigued	21	14.5
	Regular running on technical trails terrains	17	11.7
	Sudden increase in weekly running distance	10	6.9
	Lack of running experience	9	6.2
	Faster running pace	9	6.2
	Lack of a warm-up routine	5	3.4
	Lack of trail running exposure / running on other surfaces more than trails	5	3.4
	Downhill running exposure	4	2.8
	Sudden increase in elevation gain	3	2.1
	Sudden increase in running intensity	2	1.4
	Higher frequency of running	1	0.7
	Not using / poor design of a training program	1	0.7
	Lack of muscle stretching	1	0.7
	Irregular training	1	0.7
Demographic profile	**All**	**2**	**1.4**
	Older age	1	0.7
	High BMI[a]	1	0.7
Injury history	**All**	**1**	**0.7**
	History of recurrent injury	1	0.7
Behavioural factors	**All**	**18**	**12.4**
	Lack of concentration	11	7.6
	Lack of sleep	5	3.4
	Listening to music while running	1	0.7
	Running while in pain	1	0.7
Equipment use	**All**	**4**	**2.8**
	Running with worn-down running shoes	3	2.1
	High running shoe heel-to-toe drop	1	0.7
Nutrition	**All**	**3**	**2.1**
	General poor nutrition / racing nutrition	3	2.1
Medication use	**All**	**1**	**0.7**
	Anti-inflammatory / muscle relaxants use	1	0.7

[a] body mass index

2.1.3. Step 3: Risk factor analysis from a cross-sectional study

When developing the TRISI, no data existed on injury risk factors among short-distance trail runners.[4] Therefore, we analysed cross-sectional data collected at the Two Oceans trail runs (10km and 22km) over four years[13] to identify risk factors associated with gradual onset running-related injuries. Using the original data, we identified injury risk factors and added all the univariate statistically significant injury risk factors ($p<0.05$) to the provisional injury risk factor list from *Step 2*.

2.1.4. Step 4: Risk factor analysis from the prospective cohort study

When developing the TRISI, no previous study had investigated injury risk factors in a prospective cohort study.[4] Therefore, we investigated injury risk factors among trail runners by conducting a prospective cohort study over six months, following runners biweekly.[8] The univariate statistically significant injury risk factors identified in this study were added to the provisional injury risk factor list from *Step 3*.

2.2. Phase 2: Relevance of the identified injury risk factors in a trail running context

We used quantitative expert opinion to determine which factors in the provisional Phase 1 injury risk factor list are relevant to trail running and if any factor not identified in phase 1 should be added to the list. The expert panel consisted of 10 panellists from seven countries (Table 2).

Each panellist received the provisional Phase 1 injury risk factor list via email for independent review. An instructional video was also sent to each panellist to ensure that no uncertainty existed in completing the questionnaire. For each risk factor listed, the panellists were given three options: "yes, this factor will increase a trail runner's risk of sustaining an injury", "no, this factor will not increase a trail runner's risk of sustaining an injury", and "opt-out: not familiar with the content and, therefore, I cannot give an opinion on whether this factor will increase a trail runner's risk for injury". To give context to the association of each risk factor with injury in trail running, panellists were encouraged to add comments to justify their selection. For an injury risk factor to be included in the TRISI, an 80% agreement level was required among panellists who had not "opted-out" of the specific factor.

Table 2: Phase 2, 4, and 5 expert panellists (n=20)

Phase	Experts	Country of employment	Sex
Phase 2: Expert panellists (n=10)	Sports medicine physician and researcher (sport and exercise medicine)	Portugal	Female
	Sports medicine physician and researcher (sport and exercise medicine)	Qatar	Male
	Sport physiotherapist, lecturer, and researcher (sport and exercise medicine)	South Africa	Female
	Sports physiotherapist and researcher (sport and exercise medicine)	Ireland	Male
	Movement scientist, lecturer, and researcher (sport and exercise medicine)	The Netherlands	Male
	Sports scientist, biokineticist, and researcher (sport and exercise medicine)	United Kingdom	Female
	Professional running coach and biokineticist	South Africa	Male
	Professional trail running coach	United States	Male
	Professional trail runner	South Africa	Male
	Recreational trail runner	South Africa	Male
Phases 4 and 5: Expert panellists (n=10)	Sports medicine physician and researcher (sport and exercise medicine)	Canada	Male
	Sports medicine physician and researcher (sport and exercise medicine)	Portugal	Male
	Sport physiotherapist	South Africa	Female
	Sport physiotherapist	Australia	Male
	Sports scientist and biokineticist	South Africa	Male
	Sports scientist, biokineticist, and trail running coach	South Africa	Male
	Professional trail running coach	New Zealand	Male
	Professional trail running coach	South Africa	Female
	Recreational trail runner	Germany	Female
	Recreational trail runner	South Africa	Female

2.3. Phase 3: Content creation for Likert scale points of each included injury risk factor

For each injury risk factor included in Phase 2, Likert scale points from 0 to 4 indicative of an increase in injury risk, were assigned by the author group (Figure 2). The descriptive content of each Likert scale point was created by the primary researcher (CTV) and reviewed by four of the authors (CJvR, WvM, EV, and EK). The suggestions of each reviewer were considered before incorporation into the final description of each risk factor's Likert scale point for every risk factor. At the end of Phase 3, we had a final list of injury risk factors and the content for each Likert scale point (0-4).

	Likert scale points				
	0	1	2	3	4
Risk factor A	Description of injury risk factor	Description of injury risk factor	Description of injury risk factor	Description of injury risk factor	Description of injury risk factor

Figure 2: Phase 3 of the TRISI development

2.4. Phase 4: Rescaling of Likert scale points

Phase 4 consisted of rescaling Likert scale points to determine numerical values (0-4) indicative of a progressive increase in risk for the specific factor. We recruited a second panel of experts consisting of 10 panellists (Table 2) and modelled their opinions in both Phase 4 and 5, using the method of human judgement modelling.[14] Each panellist received an online document with each injury risk factor, clearly described by five Likert scale points (0, 1, 2, 3, 4). Each panellist also received an additional instructional video explaining their task related to Phase 4. The panellists were asked to indicate increased injury risk on a Likert like visual analogue scale (VAS) of 0-10, where a higher value indicated a higher risk for injury. The values for each Likert scale point were set equal to their distances from 0 and were then rescaled to fall between 0 and 1. The distance from 0 was calculated across all panellist scores for each Likert scale point and then averaged to obtain the final weighted numerical value.

2.5. Phase 5: Assign weightings to each risk factor contributing to the composite score

It can be reasoned that not all factors have an equal contribution to injury risk in trail running. Therefore, we implemented an additional step to provide an assumed weighting factor (fixed score) for each injury risk factor's contribution to the final composite score of the TRISI. A higher fixed score would indicate a risk factor with a potentially stronger contribution to increased injury risk in trail running compared to risk factors with a lower fixed score in the TRISI score rank order. Each panellist received an online questionnaire (Qualtrics platform) with an instructional video to independently assess the relative risk ranking of the injury risk factors listed in the TRISI. A visual analogue scale (VAS) ranked each risk factor by comparing them separately to all other risk factors using a visual analogue scale (VAS). The panellists had to indicate which of the two injury risk factors being compared was ranked for higher risk for

injury in trail running and the relative difference in assumed injury risk. The risk factors were ranked based on their highest assumed risk, where the highest assumed risk refers to a Likert scale score of 4. We implemented pairwise ratios of importance[14], where the decisions of each panellist contributed to their judgement matrix with a_{ij}, representing the importance of RF_i compared to RF_j (RF = risk factor). For each pairing, the relationship between risk factors was calculated by dividing the distance of VAS points for RF_i by the remaining distance for RF_j:

RF_i 0 _____8____ 10 RF_j therefore, $\frac{i\ (VAS\ distance\ from\ 0)}{j\ (remaining\ distance\ to\ 10)} = \frac{8}{2} = 4$

To obtain weighted fixed scores for each factor's assumed contribution to the composite score in the final TRISI, the judgment matrices supplied by each panellist was presented as a general linear model. The estimate of the ratios of the elements of w (a_{ij}) can be supplied by: $a_{ij}^{(k)} = \frac{wi}{wj} f_{ij}^{(k)}$, where a_{ij} represents the relative weight of RF_i compared to RF_j and where random errors fij^k are introduced. By taking the logarithmic value of XYZ, the model can be expressed as a general linear model $lna_{ij}^{(k)} = lnw_i - lnw_j + e_{ij}^{(k)}$. The estimates can be obtained using ordinary least squares regression and not fitting the constant. The weights were also rescaled to add up to 100. The final composite score is calculated by firstly multiplying the weighted fixed score for each risk factor by the ranked Likert scale point's numerical value for each injury risk factor, and then adding up the final scores obtained at each risk factor: *Composite score* = $RF_1 (a_1) + RF_2 (a_2) + \ldots\ldots\ldots\ldots RF_{27} (a_{27})$, where (a_i) represents the numerical value for the specific injury risk factor's ranked Likert scale point.

3. RESULTS

In this section, we present the results of each of the five phases of the study.

3.1. Phase 1: Identification of possible injury risk factors

Following the four steps, 77 injury risk factors were identified in Phase 1.

3.1.1. Step 1: Literature search

Our search strategy produced 849 results (CINAHL, n=287; Health Source: Nursing/Academic Edition, n=56; MEDLINE, n=201; and SPORTDiscus, n=305), of which 42 studies met the

inclusion criteria. Among the included studies, 65 different statistically significant injury risk factors were reported in the categories of trail running,[15] all running,[16-54] and runners' opinion on factors associated with a higher risk for injury[55 56] (Table 3).

3.1.2. Step 2: Trail runners' opinion

Among the 152 trail runners who received an email, 64 responded to the questionnaire. A total of 145 various responses were recorded, reporting 27 different injury risk factors (Table 2).

3.1.3. Step 3: Risk factor analysis from a cross-sectional study

Among the 2824 trail running race entrants, eight different injury risk factors were identified in the univariate analysis of the original data (Table 3).

3.1.4. Step 4: Risk factor analysis from a prospective cohort study:

Among the 152 trail runners, seven different injury risk factors were identified in the univariate analysis of the original data (Table 3).

3.2. Phase 2: Relevance of the identified injury risk factors in a trail running context

Of the 77 unique injury risk factors identified during phase 1, among the panellists, an 80% agreement level was obtained on 29 risk factors (Table 3). Three of these factors that reached 80% agreement level were excluded, based on the inability to measure them using basic equipment during a clinical screening process (i.e., lack of concentration during running; 100%; higher peak braking force: 88%; and narrower bimalleolar width: 80%). The panellists did not identify any additional risk factors than those brought forward from phase 1. Therefore, 26 injury risk factors were included in the TRISI (Table 3).

Table 3: Initial list of potential injury risk factors and panellists' level of agreement (%) on the relevance of these factors in trail running

Category	Potential injury risk factors in trail running	Injury risk factors identified through studies conducted by the research team			Injury risk factors identified through a literature search			Level of agreement (%) among panellists
		Prospective cohort study	Cross-sectional study	Trail runner's opinion	Trail running literature	All running literature	Runner opinion-based studies	
Training	No supervised running training plan	-	-	X	X [15]	-	X [56]	80*
	Competitive training	-	-	-	-	-	X [56]	80*
	Training with more advanced running partners	-	-	-	-	-	X [56]	80*
	Regular participation in running races	-	-	-	-	-	X [56]	63
	Not performing regular stretching	-	-	X	-	-	X [56]	60
	Not performing a warm-up routine before running	-	-	X	-	-	X [56]	78
	Lack of interval training	-	-	-	-	X [17]	-	50
	Regular alternating between high and low distance runs	-	-	-	-	X [18]	-	20
	Higher weekly running distance	X	X	-	-	-	-	75
	Multiple training sessions per day	-	-	-	X [15]	-	-	70
	Higher number of running sessions per week	X	-	-	-	-	-	90*
	Lack of recovery	-	-	X	-	-	X [55]	100*
	High total weekly running distance	X	-	-	-	-	-	75
	Sudden increase in weekly running distance	-	-	X	-	X [19 20 21]	X [55]	100*
	Irregular training	-	-	X	-	-	X [56]	80*
	Higher running intensity	-	-	-	-	X [22]	-	80*
	More running experience	-	X	-	X [15]	X [23]	-	0
	Lack of running experience (<5 years)	-	-	-	-	X [17 25 24 27]	X [56]	60
	Running on asphalt more often than on trails	-	-	-	X [15]	X [26]	-	67
	Faster running pace	-	-	X	-	-	X [56]	40
	Slower running pace	X	-	-	-	-	-	10
	Uphill running (elevation gain)	-	-	X	-	-	X [56]	33

Category	Potential injury risk factors in trail running	Injury risk factors identified through studies conducted by the research team			Injury risk factors identified through a literature search			Level of agreement (%) among panellists
		Prospective cohort study	Cross-sectional study	Trail runner's opinion	Trail running literature	All running literature	Runner opinion-based studies	
	Downhill running (elevation loss)	-	-	X	-	-	X [56]	56
	Running at higher altitudes	X	-	-	-	-	-	14
	Lack of muscle strengthening	-	-	X	-	-	X [56 55]	78
	Regular running on irregular terrain.	-	-	X	-	X [18]	X [56]	20
	Running while listening to music	-	-	X	-	-	X [56]	33
	Previous sports participation without axial loading	-	-	-	-	X [28]	-	40
Equipment	Lack of cushioning in running shoes	-	-	-	-	-	X [56]	70
	Buying running shoes based on a running analysis and not primarily based on a good fit	-	-	-	-	X [31]	-	100*
	Low heel-to-toe drop in running shoes	-	-	-	-	-	X [56]	40
	Evidence that the shoes are worn down	-	-	-	-	-	X [56]	90*
	Running with only one pair of shoes	-	-	-	-	X [26 30]	-	44
	Rapid transition from cushioned shoes to using minimalist running shoes	-	-	-	-	X [33]	-	100*
	Use of orthotics in running shoes	-	-	-	-	X [32]	-	44
Demographic profile	Occupations that involve physical labour	-	-	-	X [15]	-	-	30
	High body mass index (BMI)[a]	-	-	-	-	X [17 25 27 26 28 36]	X [56]	80*
	Low BMI[a]	-	-	-	-	X [23]	-	60
	Male	-	-	-	-	X [27 34]	-	0
	Female	-	-	-	-	X [35]	-	13
	Older age	-	-	-	-	X [25 36]	X [56]	56
	Younger age	-	-	-	-	X [24]	-	33
Injury history	History of previous injury (musculoskeletal complaint) not related to sports	-	-	-	-	X [25 36]	-	100*
	History of previous running-related injury (past 12 months)	X	-	-	-	X [20 23 27 28 32 37 29 38 41]	X [56]	100*
	Current injury	X	-	-	-	-	-	100*

Category	Potential injury risk factors in trail running	Injury risk factors identified through studies conducted by the research team			Injury risk factors identified through a literature search			Level of agreement (%) among panellists
		Prospective cohort study	Cross-sectional study	Trail runner's opinion	Trail running literature	All running literature	Runner opinion-based studies	
Behavioural factors	Ignoring pain while running	-	-	X	-	-	X [56 55]	90*
	Lack of concentration during running	-	-	X	-	-	X [56]	100*
	Runners motivated by external pressure	-	-	-	-	X [39]	-	78
	Non-competitive runners	-	-	-	-	X [36]	-	0
	Poor sleep quality	-	-	X	-	X [21]	-	100*
Psychological factors	Periods of psychological stress	-	-	-	-	-	X [56 55]	100*
	Running while mentally fatigued	-	-	-	-	X [40]	-	100*
Nutrition	Runner's perception of having an unbalanced diet	-	-	-	-	-	X [56]	44
Chronic disease	Presence of any haematological or immune disease	-	X	-	-	-	-	75
	Symptoms of cardiovascular disease	-	X	-	-	-	-	89*
	Risk factors for cardiovascular disease	-	X	-	-	-	-	67
	Having a current respiratory disease	-	X	-	-	-	-	100*
	History of allergies	-	X	-	-	-	-	44
Medication use	The use of AAIM[b] in the week before or during racing	-	X	-	-	-	-	78
Physiological factors	Low bone mineral density	-	-	-	-	X [16]	-	100*
	Oligo/amenorrhea	-	-	-	-	X [18]	-	100*
Biomechanical variables	Higher peak braking force	-	-	-	-	X [42 43]	-	88*
	Lower step rate during running (≤164 steps per min)	-	-	-	-	X [46]	-	60
	Leg length discrepancy > 1.5cm	-	-	-	-	X [47]	-	78
	Poor hip abductor muscle strength	-	-	-	-	X [44 45]	-	89*
	Poor knee extensor muscle strength	-	-	-	-	X [44 48]	-	100*
	Poor knee flexor muscle strength	-	-	-	-	X [44]	-	100*
	Increased peak external knee abduction moment (knee varus)	-	-	-	-	X [49]	-	67
	Rearfoot strike during running	-	-	-	-	X [50 51]	-	22
	High peak rearfoot eversion	-	-	-	-	X [45]	-	50

Category	Potential injury risk factors in trail running	Injury risk factors identified through studies conducted by the research team			Injury risk factors identified through a literature search			Level of agreement (%) among panellists
		Prospective cohort study	Cross-sectional study	Trail runner's opinion	Trail running literature	All running literature	Runner opinion-based studies	
	Increased stride length during running	-	-	-	-	X [50]	-	63
	Narrow step width during running (cross-over running style)	-	-	-	-	X [52]	-	38
	Highly supinated foot	-	-	-	-	X [26]	-	63
	Highly pronated foot	-	-	-	-	X [26]	-	63
	Greater pressure on the medial side of the shoe during running	-	-	-	-	X [45 53]	-	29
	Narrower bimalleolar width ≤ 70.5 mm	-	-	-	-	X [54]	-	80*
	Earlier peak pressure under the fifth metatarsal, indicative of earlier supination	-	-	-	-	X [54]	-	57

*: ≥80% level of agreement
[a] body mass index
[b] analgesic/anti-inflammatory medication

3.3. Phase 3: Content creation for Likert scale points of each included injury risk factor

Consensus among the author group was reached on the content created for each Likert scale point for the 26 included injury risk factors (Table 3). Multiple elements were created per Likert scale point for seven injury risk factors (numbers 1-3, 10, 13, 14, and 16). For six injury risk factors (numbers 9, 15, 20-23) only a "yes" or "no" option was possible, and therefore only two Likert scale point options are presented (0 or 1). Additional annexures were added to nine injury risk factors (numbers 6, 8, 10, 12, 18, 19, 24-26). These annexures aimed to further explain to the clinician the evaluation method and provide links to the questionnaires used to assess certain risk factors (Table 4).

Table 4: Trail running injury screening instrument (TRISI)

Injury risk factor	Higher Likert scale value indicative of a higher risk for injury					Fixed score
	0	1	2	3	4	
1) Not adhering to a specific running-related, supervised training plan	Runner adheres to a supervised running-related training plan.	Runner adheres to a supervised running-related training plan.	Runner adheres to a supervised running-related training plan.	Runner adheres to an unsupervised running-related training plan.	No running-related training plan.	**5.41**
	Training plan is designed by an experienced running coach.	Training plan is designed by an experienced running coach.	Training plan is designed by an experienced running coach.	Training plan is designed by an inexperienced individual/coach or following a generalised training plan.	No running-related training plan.	
	Updated according to the runner's progression (once every 2 weeks).	Updated according to the runner's progression (once per month).	Updated according to the runner's progression (< once per month)	Training plan is designed once-off (no updates according to the runner's progression).	Not adhering to a supervised running-related training plan.	
Likert scale point values	**0**	**0.1526**	**0.3673**	**0.7460**	**1**	
2) Competitive running	Not competing with his/her own personal records in training.	Not competing with his/her own personal records in training.	Competes with his/her own personal records in training but follows a gradual build-up in training to attempt new records over longer periods.	Competes with his/her own personal records in training but follows a gradual build-up in training to attempt new records over longer periods.	Competes with his/her own personal records in training and frequently attempts to set new personal records. Not following a gradual loading approach to achieve the goal.	**5.11**
	Not competing with fellow runners in training.	Not competing with fellow runners in training.	Not competing with fellow runners in training	Infrequently (<4x per month) competes with fellow runners in training	Frequently (≥4x per month) competes with fellow runners in training	
	Not participating in running races.	Participates in running races, but not competing with own personal records or fellow runners in races (average running pace in races is similar to training).	Competes against own personal records, but not against fellow runners in races.	Competes against own personal records and fellow runners in races.	Competes against own personal records and fellow runners in races.	
Likert scale point values	**0**	**0.1104**	**0.2361**	**0.5128**	**1**	

Injury risk factor	Higher Likert scale value indicative of a higher risk for injury					Fixed score
	0	1	2	3	4	
3) Training with more advanced running partners (At least once per week) The more advanced runner's capabilities set the tone for the session	The runner trains with running partner(s) that run at a lower average running pace.	The runner trains with running partner(s) that run at a similar running pace.	In this category, one of the three factors must be more advanced than the runner's capabilities: -Faster running pace -Higher weekly running distance -More technical running surfaces	In this category, two of the three factors must be more advanced than the runner's capabilities: -Faster running pace -Higher weekly running distance -More technical running surfaces	In this category, all of the three factors must be more advanced than the runner's capabilities: -Faster running pace -Higher weekly running distance -More technical running surfaces	**4.79**
	The runner trains with running partner(s) that run lower combined average weekly running distances.	The runner trains with running partner(s) that run similar combined weekly running distances.	As above	As above	As above	
	The runner trains with running partner(s) on less technical running surfaces than what he/she is used to.	The runner trains with running partner(s) on similar running surfaces than what he/she is used to.	As above	As above	As above	
Likert scale point values	**0**	**0.1817**	**0.4524**	**0.7101**	**1**	
4) Higher number of running sessions per week Compared to the average number of running sessions over the past 4 weeks	No increase in the number of running sessions per week. (Includes all forms of running: road, trail, treadmill, track etc.).	The runner included 1 additional running session per week. (Includes all forms of running: road, trail, treadmill, track etc.).	The runner included 2 additional running sessions per week. (Includes all forms of running: road, trail, treadmill, track etc.).	The runner included 3 additional running sessions per week. (Includes all forms of running: road, trail, treadmill, track etc.).	The runner included >3 additional running sessions per week. (Includes all forms of running: road, trail, treadmill, track etc.).	**4.70**
Likert scale point values	**0**	**0.1878**	**0.4608**	**0.7910**	**1**	
5) Sudden increase in weekly running distance Compared to the average of the past 4 weeks	0-10% increase in running distance per week	11-30% increase in running distance per week	31-45% increase in running distance per week	46-59% increase in running distance per week	≥60% increase in running distance per week	**2.54**
Likert scale point values	**0**	**0.2812**	**0.6507**	**0.8635**	**1**	

Injury risk factor	Higher Likert scale value indicative of a higher risk for injury					Fixed score
	0	1	2	3	4	
6) Lack of recovery Starting a running session while still feeling fatigued, as measured on the Rating of Fatigue (ROF) scale.[57] (Annexure A)	Highest score of 0 (ROF scale) at the start of any running session done in the past week.	Highest score of 1-2 (ROF scale) at the start of any running session done in the past week.	Highest score of 3-4 (ROF scale) at the start of any running session done in the past week.	Highest score of 5-7 (ROF scale) at the start of any running session done in the past week.	Highest score of 8-10 (ROF scale) at the start of any running session done in the past week.	**2.80**
Likert scale point values	**0**	**0.1626**	**0.3883**	**0.6903**	**1**	
7) Irregular training (running) Not getting consistent training over the past 4 weeks – interrupted by busy work schedule, illness, injury, vacation etc.	The runner was able to run (at his/her usual average number of running sessions per week) during all of the past 4 weeks.	The runner was able to run (at his/her usual average number of running sessions per week) during 3 weeks of the past 4 weeks.	The runner was able to run (at his/her usual average number of running sessions per week) during 2 weeks of the past 4 weeks.	The runner was able to run (at his/her usual average number of running sessions per week) during 1 week of the past 4 weeks.	The runner was able to run at his/her usual average number of running sessions per week for none of the past 4 weeks.	**4.16**
Likert scale point values	**0**	**0.1750**	**0.4038**	**0.6273**	**1**	
8) High running intensity Measured on the Borg Rating of Perceived Exertion (RPE) scale.[58] (Annexure B)	Highest score of 6-9 (RPE scale) during any running session in the past week.	Highest score of 10-13 (RPE scale) during any running session in the past week.	Highest score of 14-16 (RPE scale) during any running session in the past week.	Highest score of 17-18 (RPE scale) during any running session in the past week.	Highest score of 19-20 (RPE scale) during any running session in the past week.	**3.99**
Likert scale point values	**0**	**0.1725**	**0.4613**	**0.7680**	**1**	
9) Buying running shoes based on a running analysis and not primarily based on a good shoe fit	YES The runner's shoes were bought primarily based on a good fit.				NO The runner's shoes were bought primarily based on a running analysis, not considering a good shoe fit.	**5.53**
Likert scale point values	**0**				**1**	
10) Evidence that the running shoes are worn down (Not related to damage to the upper part of the shoe. Refers to uneven wear on the soles and permanent midsole cushioning collapse) (Annexure C)	No signs of wear and tear on the running shoes.	Minimal sign of uneven wear of the sole	Moderate sign of uneven wear of the sole	Moderate sign of uneven wear of the sole	Severe sign of uneven wear of the sole	**4.17**
		Minimal midsole cushioning collapse	Moderate midsole cushioning collapse	Moderate midsole cushioning collapse	Severe midsole cushioning collapse	
	Mileage on the shoes is <500km.	Mileage on the shoes between 500-699km.	Mileage on the shoes between 700-899km.	Mileage on the shoes between 900-1099km.	Mileage on the shoes is > 1100km.	

Injury risk factor	Higher Likert scale value indicative of a higher risk for injury					Fixed score
	0	1	2	3	4	
Likert scale point values	**0**	**0.1931**	**0.4764**	**0.7069**	**1**	
11) Rapid transition from cushioned running shoes to using minimalist running shoes (in the final instrument, this will only apply to runners who recently transitioned from cushioned to minimalistic shoes)	Transitioned from cushioned running shoes to minimalistic running shoes over a period of ≥12 months.	Transitioned from cushioned running shoes to minimalistic running shoes over a period of 6-12 months	Transitioned from cushioned running shoes to minimalistic running over a period of 2 to <6 months.	Transitioned from cushioned running shoes to minimalistic running shoes over a period of < 2 months	Transitioned from cushioned running shoes to minimalistic running shoes immediately.	**2.64**
Likert scale point values	**0**	**0.1983**	**0.4802**	**0.7354**	**1**	
12) High body mass index (BMI) Normative values according to the World Health Organisation (WHO) European regional office. (Annexure D)	BMI = 18.5 - 24.9 (Normal weight)	BMI = 25.0 - 29.9 (Pre-obesity)	BMI = 30.0 - 34.9 (Obesity class I)	BMI = 35.0 - 39.9 (Obesity class II)	BMI = 40 or above (Obesity class III)	**4.10**
Likert scale point values	**0**	**0.2345**	**0.5480**	**0.7990**	**1**	
13) History of previous injury Any musculoskeletal complaint during the past 12 months not related to sports participation	No injury was sustained during the past 12 months.	Sustained an injury during the past 10-12 months.	Sustained an injury during the past 7-9 months.	Sustained an injury during the past 4-6 months.	Sustained an injury during the past 3 months or less.	**4.36**
	No modification to training (running) as a result of injury	The injury resulted in a modification to training (running)	The injury resulted in a modification to training (running)	The injury resulted in a modification to training (running)	The injury resulted in a modification to training (running)	
		Full rehabilitation period completed, under the guidance of an experienced clinician.	Partial rehabilitation period completed, under the guidance of an experienced clinician.	Improper rehabilitation guided by an inexperienced clinician (Poor adaptation to sport-specific loading requirements following injury).	No rehabilitation (No adaptation to sport-specific loading requirements following injury).	
Likert scale point values	**0**	**0.1889**	**0.4010**	**0.7627**	**1**	
14) History of previous running-related injury (RRI) (past 12 months)	No RRI was sustained during the past 12 months.	Sustained an RRI during the past 10-12 months.	Sustained an RRI during the past 7-9 months.	Sustained an RRI during the past 4-6 months.	Sustained an RRI during the past 3 months or less.	**3.90**

Injury risk factor	Higher Likert scale value indicative of a higher risk for injury					Fixed score
	0	1	2	3	4	
"Running-related (training or competition) musculoskeletal pain in the lower limbs that causes a restriction on or stoppage of running (distance, speed, duration, or training) for at least 7 days or 3 consecutive scheduled training sessions, or that requires the runner to consult a physician or other health professional".[59]		Full rehabilitation period completed, under the guidance of an experienced clinician.	Partial rehabilitation period completed, under the guidance of an experienced clinician.	Improper rehabilitation guided by an inexperienced clinician (Poor adaptation to sport-specific loading requirements following injury).	No rehabilitation (No adaptation to sport-specific loading requirements following injury).	
Likert scale point values	**0**	**0.2208**	**0.4357**	**0.7891**	**1**	
15) Current RRI "Running-related (training or competition) musculoskeletal pain in the lower limbs that causes a restriction on or stoppage of running (distance, speed, duration, or training) for at least 7 days or 3 consecutive scheduled training sessions, or that requires the runner to consult a physician or other health professional".[59]	NO Not currently injured.				YES Has a current injury.	**2.33**
Likert scale point values	**0**				**1**	
16) Ignoring pain while running Runner currently participates in running activity even though pain is present during running (this pain can be of any intensity)	The runner stops a running session in the presence of pain	The runner keeps on running in the presence of pain	The runner keeps on running in the presence of pain	The runner keeps on running in the presence of pain	The runner keeps on running in the presence of pain	**2.21**
	No pain during running	Pain is present only at the beginning of a running session and quickly dissipates	Pain is present throughout the running session – Pain remains at the same intensity throughout the session	Pain is present throughout the running session – Pain intensity worsens during the running session	Pain is present throughout the running session – Pain worsens during the running session	
	Running style and pace are not affected by pain	Running style and pace are not affected by pain	Running style and pace are affected by pain	Running style and pace are affected by pain	The runner needs to intermittently stop running during a session due to pain.	
Likert scale point values	**0**	**0.1847**	**0.5552**	**0.8552**	**1**	

Injury risk factor	Higher Likert scale value indicative of a higher risk for injury					Fixed score
	0	1	2	3	4	
17) Insufficient sleep (hours)	On average, sleeps 7-9 hours at night.	On average, sleeps 6 hours at night.	On average, sleeps 5 hours at night.	On average, sleeps 4 hours at night.	On average, sleeps < 4 hours at night.	**4.61**
Likert scale point values	**0**	**0.3081**	**0.5343**	**0.8173**	**1**	
18) Current state of perceived psychological stress Measured by the Perceived Stress Scale (PSS). (Annexure E)	PSS score of 0. (No stress).	PSS score of 1-13. (Low stress).	PSS score of 14-26. (Moderate stress).	PSS score of 27-33. (High stress).	PSS score of 34-40. (High stress).	**4.74**
Likert scale point values	**0**	**0.2156**	**0.4705**	**0.7799**	**1**	
19) Running while feeling mentally fatigued Measure similar to Abassi et al. (2018) with a visual analogue scale (VAS) to evaluate mental fatigue.[60] (Annexure F)	Mental Fatigue VAS 0 during running in the past week.	Mental Fatigue VAS 1-2 during running in the past week.	Mental Fatigue VAS 3-5 during running in the past week.	Mental Fatigue VAS 6-8 during running in the past week.	Mental Fatigue VAS 9-10 during running in the past week.	**4.56**
Likert scale point values	**0**	**0.1661**	**0.3663**	**0.7512**	**1**	
20) Having symptoms of cardiovascular disease: Swollen ankles, abnormal shortness of breath (with exercise), chronic dry cough, palpitations, chest pain, pain (or discomfort) in the neck, jaw, or arms at rest or during exercise, dizziness, fainting spells, and/or calf pain when cycling/ running/ walking/ swimming.	NO No symptoms of cardiovascular disease.				YES The runner has symptoms of cardiovascular disease.	**3.00**
Likert scale point values	**0**				**1**	
21) Having a current respiratory disease Respiratory (lung) disease including asthma, emphysema, chronic obstructive pulmonary disease (COPD), wheezing, cough, postnasal drip, hay fever, or repeated flu-like illness.	NO The runner has no current respiratory disease.				YES The runner currently has a respiratory disease.	**3.43**

Injury risk factor	Higher Likert scale value indicative of a higher risk for injury					Fixed score
	0	1	2	3	4	
Likert scale point values	**0**				**1**	
22) Low bone mineral density Having any condition related to low bone mineral density (Osteoporosis, Osteopenia)	NO The runner has no condition related to low bone mineral density				YES The runner has a condition related to low bone mineral density	**3.32**
Likert scale point values	**0**				**1**	
23) Oligo / Amenorrhea (in the final instrument, this option will only apply to females runners) For non-medical panellists: This relates to physiological adaptations (hormonal disturbances, energy deficiencies, suppressed anabolic states etc.), exposing the female runner to risk of injury.	NO Not diagnosed with oligomenorrhea / did not go >90 days without a menstrual period Not diagnosed with amenorrhea				YES The runner was diagnosed with oligomenorrhea / >90 days without a menstrual period Diagnosed with amenorrhea/absence of menstrual period	**3.31**
Likert scale point values	**0**				**1**	
24) Decreased hip abductor muscle strength Oddvar Holten diagram (Annexure G) estimated one-repetition maximum (1RM) test Position: standing, cable pull	Similarly estimated 1RM compared to baseline.	1-5% lower estimated 1RM compared to baseline	6-10% lower estimated 1RM compared to baseline	11-15% lower estimated 1RM compared to baseline	>15% lower estimated 1RM compared to baseline	**4.00**
Likert scale point values	**0**	**0.1567**	**0.4244**	**0.6987**	**1**	
25) Decreased knee extensor isokinetic muscle strength Oddvar Holten diagram (Annexure H) estimated 1 RM test Knee extension gym machine	Similarly estimated 1RM compared to baseline.	1-5% lower estimated 1RM compared to baseline	6-10% lower estimated 1RM compared to baseline	11-15% lower estimated 1RM compared to baseline	>15% lower estimated 1RM compared to baseline	**3.86**
Likert scale point values	**0**	**0.1590**	**0.4088**	**0.7348**	**1**	

Injury risk factor	Higher Likert scale value indicative of a higher risk for injury					Fixed score
	0	1	2	3	4	
26) Decreased knee flexor muscle strength Oddvar Holten diagram (Annexure I) estimated 1 RM test Hamstring curl gym machine	Similarly estimated 1RM compared to baseline.	1-5% lower estimated 1RM compared to baseline	6-10% lower estimated 1RM compared to baseline	11-15% lower estimated 1RM compared to baseline	>15% lower estimated 1RM compared to baseline	**2.43**
Likert scale point values	**0**	**0.1567**	**0.4140**	**0.7343**	**1**	

Composite score	**100**

3.4. Phase 4: Rescaling of Likert scale points

In Table 3, we present numerical values determined for each Likert scale point of each injury risk factor. No numerical values were determined for injury risk factors number 9, 15, 20-23 as only "yes" or "no" options are available. For these factors, a value of "0" was assigned "no" and "1" assigned to "yes".

3.5. Phase 5: Assign weightings to each risk factor contributing to the composite score

A weighted score for each injury risk factor included in the TRISI is presented in Table 3. The score ranged from 2.21 to 5.53 and contributed to a composite score of 100. The highest calculated scores were 5.53 (buying running shoes based on a running analysis and not primarily based on a good shoe fit), followed by 5.41 (not adhering to a specific running-related, supervised training plan), and 5.11 (competitive training) (Table 3). The final TRISI includes risk categories of training, running equipment, demographics, previous injury, behavioural, psychological, nutrition, chronic disease, physiological, and biomechanical.

4. DISCUSSION

Sports-related injuries have a multifactorial origin resulting from complex interactions between various contributing factors.[61] A phenomenon such as injury risk in trail running cannot be ascribed to a single risk factor. To account for multiple factors, we utilised two expert panels to design a TRISI. The TRISI is based on multiple items (i.e., multiple injury risk factors), each with a weighted score contributing to a composite injury risk score.

Most injury prediction models lack predictive performance as statistical "small world" models are applied to "large world" realities where uncertainty exists.[62] This highlights the need to not fully rely on statistical models in injury risk management decision-making. The clinician's clinical expertise should be included in the process to construct evidence-based advice regarding the focus of the risk management strategy for a particular individual.[62] Importantly, the TRISI was not designed to predict injury but to aid in clinical decision-making by enhancing the clinical expertise pillar of EBM in light of the current lack of trail running injury literature. This can assist the clinician during pre-race injury screening or during a training season to highlight meaningful areas to target in designing injury risk management strategies.[63]

4.1. Application of the TRISI in clinical practice

The TRISI will be made available as an application hosted on the latest Android and iPhone Operating Systems. Clinicians will be able to create a secure online profile for each individual trail runner consulting them. The TRISI will adhere to the Protection of Personal Information Act (POPI) and the General Data Protection Regulation (GDPR). The clinician will be guided on scoring each risk factor based on the information obtained through the trail runner's interview or physical assessment. Online annexures are provided for risk factors 6, 8, 10, 12, 18, 19, and 24-26. Here we either provide online links to the relevant questionnaires or explain how to perform difficult physical assessments via the YouTube online platform.

4.1.1. Injury screening of the injured vs non-injured trail runner

The aim of screening is for clinicians to identify meaningful areas of interest to address individualised injury risk management strategies to mitigate the trail runner's risk of injury during training or racing. A baseline assessment of risk factors 24-26 will be required as the change in muscle strength in a follow-up screening, will be compared to the trail runner's baseline muscle strength.

During the screening of a *non-injured trail runner*, we still encourage clinicians to continue using clinical reasoning and incorporate the assessment of risk factors not included in the TRISI but relevant to the individual trail runner. For example, suppose a trail runner is screened five months before a race hosted in a desert environment. In that case, it will be important to further question the trail runner on how his/her current training plan is structured for optimal musculoskeletal conditioning leading up to the race.

For *injured trail runners*, clinicians should incorporate the TRISI into their clinical injury assessment procedure. In this case, the aim will be for clinicians to identify areas of interest in injury risk management strategies aimed towards mitigating the trail runner's risk upon returning to full running participation. It will further highlight risk factors that might have contributed to the current injury. The TRISI has 21 factors in assessing as part of the patient interview (1-9, 11, 13-23) and five factors (10, 12, 24-26) as part of the physical assessment. These factors should not be assessed separately before or after a normal patient assessment procedure. We advise incorporating the TRISI in the normal injury assessment procedure when questioning or physically assessing a specific category of interest to maintain a logical flow of the assessment. For example, factors 4, 5, 7, and 8 can be assessed during the interview when

the trail runner is questioned on his/her current and past training exposure regarding frequency, intensity, time, and type of training. While factors 24-26 can be assessed later in the physical assessment during muscle strength testing. Clinicians should be aware that certain factors' estimated injury risk can be hyperinflated when screening an injured trail runner. For example, when a trail runner presents with an acute hamstring strain, then factor 26 will likely score higher for injury risk due to the trail runner's current lower hamstring muscle strength affected by pain. Also, certain factors might not be relevant for injured trail runners as they will likely modify their training or stop all running participation. For example, a trail runner that sustained a recent acute ankle sprain with resulting pain on ankle weight-bearing will likely stop running participation for several days. During the screening, this runner will show no risk for factor 8 as he/she might not have run during the past week. In this case, the clinician should assess factor 8 based on the period before the injury. This might be a factor of interest that scored high for injury risk before the injury and therefore needs to be addressed in patient education as part of injury risk management upon return to full running participation.

We acknowledge that a clinician might experience an assessment to be more time consuming when initially incorporating the TRISI into their normal patient assessment procedure. However, clinicians should familiarise themselves with the content of the TRISI before an assessment and plan where they will incorporate the specific factors of the TRISI into their normal preferred flow of an assessment procedure.

4.1.2. Injury screening focussed on general training vs race participation

For recreational *trail runners not participating in races*, we advise performing a baseline injury screening before a new running season or at the beginning of a new year in cases where no distinct running season exists. The more frequently a trail runner is screened in follow-up consultations, the more promptly areas of interest for risk mitigation can be identified. Frequent screening may also account for the temporality of risk factors.[61] We acknowledge that frequent screening might not be possible due to the cost of medical care. The principle will be to screen frequently within what is reasonable and financially affordable for the individual trail runner.

For *trail running race participation*, we advise performing a baseline injury screening at least six months before the race. This will allow the needed time to implement, adjust, and see the needed effect of the injury risk management strategy based on the identified areas of higher risk for injury. Similar to general training, we advise frequent follow-up screenings leading up

to the race. Race medical directors can implement an injury screening process for race entrants up to three weeks before the race. Here the aim will be to flag trail runners as presenting with higher injury risk. The TRISI cannot predict injury or predict which trail runners will sustain serious injuries requiring emergency evacuation from the course. Therefore, clinicians cannot by applying the TRISI, advise race medical directors on who to withdraw from a race. The higher risk of injury should be reported. Still, it remains the race medical director's decision on how to use the information provided during their race medical preparation in the context of the specific race's policy.

4.1.3. TRISI scoring and interpretation

The clinician should select the Likert scale point at each risk factor that relates to the information provided by the trail runner, or the results obtained from a physical assessment. Most risk factors have either simple "yes/no" options (risk factors 9, 15, 20-23) or have only one element to consider for each Liker scale point (risk factors 4-8, 11, 12, 17-19, 24-26). However, risk factors 1-3, 10,13, 14, and 16 have multiple elements to consider at each Likert scale point. Here a trail runner can only be downgraded in injury risk (lower assigned Likert scale point value) if all elements of the specific Likert scale is met. For example, if considering risk factor 1, the trail runner adheres to a supervised training plan created by an experienced running coach, but the training plan was never updated then Likert scale point 3 should be selected. If a specific factor does not apply to the specific runner, then Likert scale point 0 should be selected. A composite score out of 100 will automatically be calculated after a selection is made at each risk factor.

Even though a higher composite score indicates a higher risk for injury, we chose not to add cut-off scores for levels of risk. We opted to emphasise the weighted scores for each risk factor to help the clinician prioritise the injury risk management strategy accordingly. Pre-set cut-off scores may influence clinicians to lose sight of applying their expertise during the injury risk assessment of a trail runner.

A follow-up implementation and feasibility trial should be conducted to get feedback from clinicians regarding the usability and user experience in applying the TRISI during the assessment of trail runners. We further advise that the TRISI be updated annually with the best available research evidence and clinical experience.

4.2. Limitations

In Step 1 of Phase 1 we may have missed relevant studies as our search was limited to studies indexed in four databases from 2009-2019 and only one researcher screened for relevant publications to be included. As a result of the low response rate in Step 2 of Phase 1, non-response bias could have affected our results. We made use of two expert panels in Phase 2, 4 and 5. We aimed towards having a diverse group of panellists representing multiple nationalities, various health professions, amateur and professional trail runners, clinicians, and researchers. However, we don't have an exact criterion of what an "expert" in the field of trail running injury risk consists of for the various professions. We acknowledge that confirmation bias could have affected the selection of our expert panels. The TRISI is designed to identify meaningful areas to target in designing injury risk management strategies and/or continuous health education. However, it cannot account for the temporality of injury risk factors without frequent follow-up screenings. The TRISI can further not account for the complexity of sports injuries as a stand-alone instrument. It still requires clinical reasoning to apply the identified areas of higher injury risk into a meaningful injury risk management strategy.

5. CONCLUSION

Using a multiple methods approach, we applied quantitative research methodology to develop a TRISI consisting of 26 injury risk factors. The TRISI aims to assist the clinician during pre-race injury screening or during a training season to identify meaningful areas to target in designing injury risk management strategies and/or continuous health education.

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CHAPTER 6

Trail Running Injury Risk Factors:

A Living Systematic Review

Published as:

Viljoen C, Janse van Rensburg DCC, 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. Trail running injury risk factors: a living systematic review. Br J Sports Med. 2022 Jan 12:bjsports-2021-104858. doi: 10.1136/bjsports-2021-104858. Epub ahead of print. PMID: 35022162.

PUBLICATION DETAILS

Title of publication:

Trail Running Injury Risk Factors: A Living Systematic Review

Journal (ISSN):	**Impact factor:**	**Date published:**
British Journal of Sports Medicine (0306-3674)	13.8	12 January 2022

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CONFRERENCE PRESENTATION DETAILS

Title:

In Pursuit of Safer Trail Running: What Evidence do we have and what is Holding us Back?

Conference:

ACSM Annual Meeting and World Congresses

Location:

San Diego, USA

Date:

31 May – 04 June 2022

Type of presentation:

Tutorial lecture

ABSTRACT

Objective: To review and frequently update the available evidence on injury risk factors and epidemiology of injury in trail running.

Design: Living systematic review. Updated searches will be done every six months for a minimum period of five years.

Data Sources: Eight electronic databases were searched from inception to 18 March 2021.

Eligibility criteria: Studies that investigated injury risk factors and/or reported the epidemiology of injury in trail running.

Results: Nineteen eligible studies were included, of which 10 studies investigated injury risk factors among 2 785 participants. Significant intrinsic factors associated with injury are: more running experience, level A runner, and higher total propensity to sports accident questionnaire (PAD-22) score. Previous history of cramping and post-race biomarkers of muscle damage are associated with cramping. Younger age and low skin phototypes are associated with sunburn. Significant extrinsic factors associated with injury are neglecting warm-up, no specialised running plan, training on asphalt, double training sessions per day, and physical labour occupations. A slower race finishing time is associated with cramping, while more than three hours of training per day, shade as the primary mode of sun protection, and being single are associated with sunburn. An injury incidence range 0.8 to 61.2 injuries/1000h of running and prevalence range 1.3% to 90% were reported. The lower limb was the most reported region of injury, specifically involving blisters of the foot/toe.

Conclusion: Limited studies investigated injury risk factors in trail running. Our review found eight intrinsic and nine extrinsic injury risk factors. This review highlighted areas for future research that may aid in designing injury risk management strategies for safer trail running participation.

PROSPERO registration number: CRD42021240832

1. INTRODUCTION

Trail running is an outdoor sport requiring runners to contend with off-road terrains, substantial elevation changes and varying running distances from a few kilometres to multi-day ultramarathons (>200 km).[1] An estimated 20 million runners participate in trail running, with a 15% increase in participation over the past decade.[2] The Ultra-Trail® World Tour circuit includes races across all six world regions.[3] The most popular race is the Ultra-Trail du Mont Blanc® in France with more than 7 000 runners partcipating each year in the various race distances.[1] Since 2021, the United Kingdom has been included in the Ultra-Trail® World Tour by adding the Ultra-Trail® Snowdonia race to the circuit.[3]

While the health benefits associated with running are well documented,[4] trail running presents with a high risk of injury.[5-9] Trail runners often participate in remote environments during training or racing, posing challenges for medical providers who need to access and/or evacuate injured runners.[10] Even though the majority of trail running injuries are minor,[7 11] in rare cases injuries are severe and even fatal.[12] This highlights the need to identify trail runners at risk of injury before training and race participation, not only to prevent rare fatal injuries but any injury, to ensure ongoing access to the health benefits related to running.[4]

A large body of evidence exists on running-related injury risk factors, with multiple previous systematic reviews on running as a whole.[13-15] However, little is known about risk factors specific to trail running, with no systematic reviews providing summarised evidence on this topic. Systematic reviews hold challenges for clinical practice as they are often outdated by the time they are published.[16 17] The maturing nature of the body of evidence in trail running, provides an opportunity to regularly summarise available literature through a living systematic review. A living systematic review is an up-to-date summary of literature on a specific topic with frequent updates of the search, risk of bias assessment and, if applicable, the conclusions.[16] Updated findings are reported in peer-reviewed publications and on a designated webpage to avoid a delay in the availability of information due to the peer-review process.[16] This will not only inform up-to-date evidence based medical practice, but also highlight and address any gaps between trail running research and the clinical application of findings within the design of injury risk management strategies.[16 17]

The primary aim of this living systematic review is to identify, summarise, and frequently update the available evidence on factors associated with injury in trail running. Our secondary

aim is to report the epidemiology (incidence, prevalence, and clinical characteristics) of injury in trail running.

2. METHODS

2.1. Protocol registration

Our protocol was registered on PROSPERO, an international prospective register of systematic reviews (CRD42021240832) with no deviations from the registered protocol. The review was conducted in line with the 2020 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines.[18]

2.2. Administration, dissemination and updating the living systematic review

The living systematic review will be administered at the Department of Physiotherapy and Section Sports Medicine, University of Pretoria, South Africa. Updated searches will be done every six months over a minimum period of five years. The results will be made available on a designated webpage (http://www.slhamsterdam.com/lsr-trailrunning) and also presented in plain language to trail runners, coaches, and clinicians to promote the translation of scientific evidence into clinical practice. An updated review will be submitted for publication when new findings result in changes to this review's conclusion or recommendations.

2.3. Eligibility criteria

All studies that met the criteria of trail running as defined by the International Trail Running Association (ITRA)[19] were eligible for inclusion, despite the various terminologies used to describe off-road running.[1] To meet the criteria for trail running, running should be performed on natural running surfaces (< 20% on paved surfaces) with no limitations on the total running distance or elevation change.[1 19] For race-participation studies, the official race website was consulted when it was unclear whether an "ultramarathon" was a trail run or not. Race distances ranging from a few kilometres to multi-day ultramarathons were included in this review under the categories of 1) sub-marathon distance (< 42.2 km), 2) marathon distance (42.2 km), and 3) ultramarathon distance (> 42.2 km). In non-race studies, the authors had to clearly state that the participants under investigation were trail runners. To ensure a comprehensive summary of injury risk factors and epidemiology of injury in trail running, we included clinical assessment, self-reported, and medical attention injuries. Even though the primary mode of injury involves

transfer of kinetic energy with resulting tissue damage, we also included injuries with different aetiologies (e.g., sunburn) in line with the 2020 International Olympic Committee (IOC) consensus statement.[20] Injury risk factors from univariate and multivariate analyses were included. We excluded studies that investigated biomarkers of potential injury, reviews, conference proceedings, case studies, case series, commentaries, and editorials.

2.4. Main outcome measures

Statistically significant (significance level as set out by each study: $p<0.05$ or $p<0.01$) injury risk/protective factors determined through either a univariate or multivariate analysis were reported (odds/risk ratio, Pearson's correlation coefficient). For the injury epidemiology, we reported the injury incidence (injuries/1000h or injuries/1000 runners) and the prevalence (%). The frequencies (n, %) related to the clinical characteristics of injury were reported in accordance with the 2020 IOC consensus statement.[20]

2.5. Literature search strategy and information source

The lead author (CTV) developed the search strategy under the guidance of a medical librarian (SS) (online supplementary appendix 1). Relevant electronic databases (MEDLINE OVID, PubMed, Scopus, SPORTDiscus, MEDLINE EBSCO, CINAHL, Health Source: Nursing/Academic via EBSCO, and Cochrane Library) were searched from inception to 18 March 2021. The search process was completed prior to registration of our protocol on PROSPERO.

To identify studies relevant to the scope in line with our research question, we used two sets of keywords during our search. Set 1 included various terminologies for trail running, while Set 2 included terminologies used for injury risk factors and the epidemiology of injury (online supplementary appendix 1). The final study selection was limited to humans, academic publications, and language (English, French, Spanish, and Portuguese). The selected studies were imported into EndNote 20.1 where one researcher (CTV) screened for duplicates.

2.6. Study selection

Two researchers (CTV and BS) independently screened the identified study titles and abstracts and thereafter reviewed the full text of the identified studies for eligibility. A third researcher (EV) was appointed to resolve any discrepancies if consensus could not be reached between

CTV and BS. However, discrepancies between CTV and BS were unanimously resolved following online consensus meetings for both the title/abstract screening and full-text review. CTV then reviewed the references of all included studies to ensure no relevant study was overlooked. For all updates, a similar process will be followed. But if needed, the data sources and search strategy will be updated and clearly described in follow-up peer-reviewed publications to remain relevant over the full study period of this living systematic review.

2.7. Data extraction

Four researchers (EV, VS, WvM, and AJvR) each received a random sample from only the included English written studies[6-9 11 21-33] to extract data from. One researcher (CTV) extracted data from all the English written studies for quality control. Data from the only Spanish study[34] was extracted by MB, and quality control was done by BS. All researchers used a standardised form for data extraction, (online supplementary appendix 2), consisting of:

- *Publication and study detail*: authors, year of publication, study design, data collection procedure, study setting (country, race distance, elevation changes, min/max temperatures, altitude), number of participants (n), follow-up period, and injury definition.
- *Participant demographics:* age (years), sex (male/female), and body mass index (BMI, kg/m^2).
- *Injury risk factors:* risk factors and/or protective factors, univariate/multivariate analyses used.
- *Epidemiology of injury:* incidence of injury (injuries/1000h or injuries/1000 runners), prevalence (% of injured participants) and clinical characteristics of injury (frequency of injured anatomical region, body area, tissue type, pathology type, and injury severity).

2.8. Quality and level of evidence assessment

A modified Downs and Black assessment tool[35] was used to assess the quality of each included study (online supplementary appendix 3). The modification involved the removal of irrelevant aspects from the original tool which related to intervention. The maximum attainable score was 15 (a higher score indicating a higher quality study). Two researchers (MS and MB) independently assessed the quality of evidence of the studies published in English.[6-9 11 21-33] The Spanish study[34] was independently assessed by MB and RGB, who are both proficient in Spanish. Any discrepancies which could not be resolved through consensus were reviewed by a third researcher (WvM) to decide on the final scoring.

For each of the included studies, the level of evidence (LoE) was determined using the Oxford Centre of Evidence-Based Medicine (OCEBM) model.[36] Prospective cohort studies with good follow-ups (>80%) were rated as level 1b and poor follow-up as level 2b. Poor quality prognostic cohort studies or case-series were rated as level 4 evidence. Two researchers proficient in English and Spanish (RGB and SM) independently assessed the LoE for all included studies, and any discrepancies between their scores were resolved through consensus between the two authors.

2.9. Data analysis

The data analysis was done by reporting on associated injury risk factors and the epidemiology of injury. Data were reported under the larger themes of *race-related* and *training/race-related* studies (training focussed, but participants might still have participated in races during the study period). Performing a meta-analysis was not appropriate due to the heterogeneous nature of the included studies in study design, data collection procedure, injury definition, statistical analysis, and running exposure.

3. RESULTS

Our search produced 2 755 records (figure 1) of which 1 124 duplicates were removed, resulting in 1631 records to be screened. 1 442 ineligible studies were excluded during the screening process, and an additional 108 duplicates were identified and excluded. The remaining 81 studies were screened, and 19 studies met the inclusion criteria for this review.

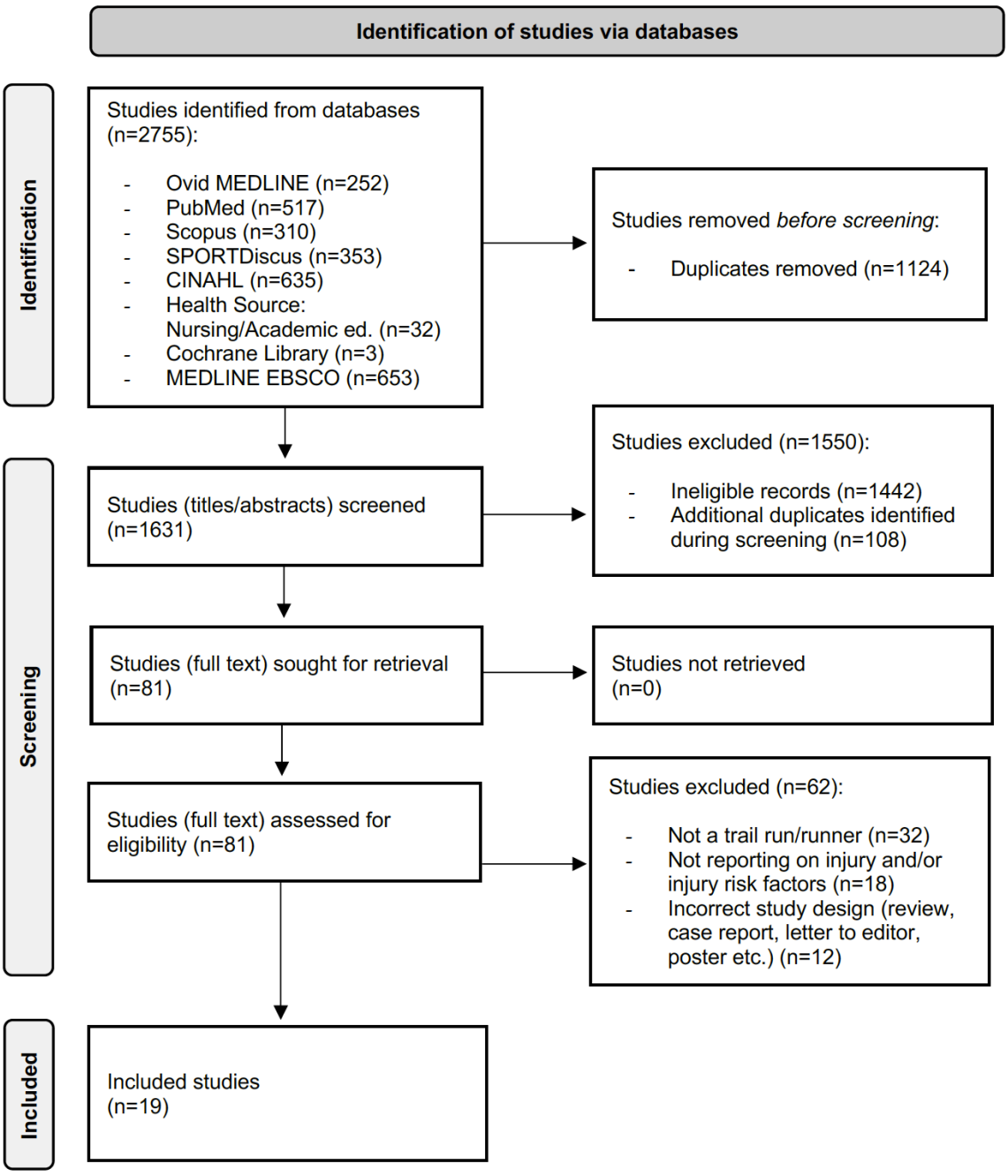

Figure 1: Preferred reporting items for systematic review and meta-analysis (PRISMA) 2020 flow diagram

3.1. Characteristics of included studies

The characteristics of the 19 included studies had a publication date range of 2011 to 2021. Thirteen studies focussed on injury outcomes related to race participation[6 7 11 22-25 27 29-32 34] (table 1). The majority of studies included ultramarathons,[6 7 23-25 27 29-32 34] followed by marathons,[11 22] and sub-marathon distances.[11] Injury outcomes related to 56 different races

(sub-marathon distance: n=34, ultramarathons: n=19, and marathons: n=3) across all six world regions (Europe,[11 23 30-32 34] North America,[25 27 29] Asia,[7 22 24] Africa,[7] South America,[7] and Oceania[6]) were included. Six studies included training-related injury outcomes[8 9 21 26 28 33] (table 2).

The majority (n=10) of race participation studies used injury definitions related to medical encounters (injuries requiring medical attention during a race)[7 22-25 29 30 32] or clinical assessments (routine assessment of all participants during the study).[6 31] All studies that included training exposure used self-reported injury data.[8 9 21 26 28 33] Injury risk factors were investigated among 2 785 participants in a total of 10 studies,[7-9 21 23 27 28 31 33 34] of which five focussed on *race participation*,[7 23 27 31 34] and five on training/race participation.[8 9 21 28 33]

Five studies collected data cross-sectionally[11 23 29 32 34] in race participation, and 10 studies recorded data prospectively with short follow-up periods (duration of the race).[6 7 22-25 27 29-31] Two studies collected data both prospectively and cross-sectionally at the different races under investigation.[23 29] Studies that included training exposure mainly collected data cross-sectionally[8 9 21] with only two studies following prospective study designs with long-term follow-up periods.[26 28]

This review included 9 763 participants of which 80.6% (n=7871) were males and 15.8% (n=1542) were females. No sex classification was reported for 3.6% (n=350) of participants. Participants' mean age ranged between 33-46 yrs (age range 17-72 yrs), and mean BMI ranged between 21.3-24.5 kg/m^2.

Table 1: Characteristics of the 13 studies that included only race-related injury outcomes

Author(s) and publication year	Study design	Data collection	Setting	Number of participants (n)	Age (yrs)	Sex	BMI (kg/m^2)	Quality and LoE [a]
Buckler & Higgins (2000)[22]	Observational Race report	Medical encounters prospectively recorded at baseline and during the race.	Tibet: 1999 Everest Marathon Altitude range: 5184-3446m Temperature: −10°C and below	70	Not reported	Not reported	Not reported	Quality 5/15 LoE[a] 4
Costa et al. (2016)[23]	Event 1: MSUM [b] Prospective Event 2: Cross-sectional	Event 1: MSUM [b] Prospective data collected over 4 days Event 2: Continuous marathon (24 h) Cross-sectional data collected at the end of the 24 h race	Event 1 (Spain) MSUM: [b] Al Andalus Ultimate Trail (2010 & 2011) Event 2 (Scotland) 24 h continuous ultramarathon: Glenmore24 Trail Race (2011 & 2012)	Event 1: MSUM [b] 54 Event 2: Continuous marathon (24 h) 22	Event 1: MSUM [b] 40 (± 8) Event 2: Continuous marathon (24 h) 40 (±7)	Event 1: MSUM [b] Males: n=33 (61%); Females: n=21 (39%) Event 2: Continuous marathon (24 h): Males: n=16 (73%); Females: n=6 (27%)	Not reported	Quality 11/15 LoE[a] 2b
Dawadi et al. (2020)[24]	Retrospective descriptive	Medical encounters	Nepal: Manaslu trail race: 7-day stage race: 212km High altitude	100 2014: 34 2015: 26 2016: 40	Not reported	Males: n=60 (60%) Females: n= 40 (40%)	Not reported	Quality 12/15 LoE[a] 4
Garcia-Malinis et al. (2020)[34]	Cross-sectional	Self-reported questionnaires	Spain: Ultra-trail race (GranTrail Aneto-Posets) 105km	657	39.7±7.9	Males: n=474 (72.1%) Females: n=183 (27.9%)	Not reported	Quality 10/15 LoE[a] 2b
Gonzales-Lazaro et al. (2021)[11]	Retrospective cohort study	Self-reported participant form recording injuries sustained during the race.	Spain: Mountain races (n=36) Mean distance: 28±6 km (95% CI [c], 26-30). Mean accumulative elevation change: 3497±717 m (3254-3740). Min temperature: 7±5°C (5-9). Max temperature: 23±7°C (20-25)	4831	40±7 (18-72)	Males: 91% Females: 9%	Not reported	Quality 9/15 LoE[a] 4
Graham et al. (2012)[6]	Observational	Injuries clinically diagnosed (daily recorded via a standardised injury reporting form).	New Zealand: 2009 Gobi Challenge, 7 stage desert race ultramarathon with a total of 150 miles (240km).	11 1 below knee amputee	33±11 Amputee age: 43	Males: n=11 (100%) Females: n=0 (0%)	24±1.8 Amputee: 25	Quality 8/15 LoE[a] 2b
Graham et al. (2021)[25]	Prospective cohort	Medical encounters recorded over 3 days during the race.	Yukon, Canada: 6633 Ultra: 120 miles (192km) ran over 3 days; Minimum temperature: −20°C	12	42 ± 5.4 yrs.	Male: n=9 (75%) Female: n=3 (25%)	Not reported	Quality 11/15 LoE[a] 2b

Author(s) and publication year	Study design	Data collection	Setting	Number of participants (n)	Age (yrs)	Sex	BMI (kg/m^2)	Quality and LoE [a]
Hoffman & Stuempfle (2015)[27]	Observational	Self-reported symptoms of muscle cramping recorded with online questionnaire post-race.	USA, California: 2014 Western States Endurance Run 161km (100miles)	280	Not reported	Not reported	Not reported	Quality 13/15 LoE[a] 2b
Krabak et al. (2011)[7]	Observational	Medical encounters: Data recorded daily over a 7-day period, during each race at a medical checkpoint (every 10 km and finish line)	4 Ultramarathons (240 km) (7-day stage race) Gobi Desert, China: 2005 & 2006 Sahara Desert, Egypt: 2005 Atacama Desert, Chile: 2006	396	40 (± 10.6) (18-64)	Males: n=314 (79.2%) Female: n=82 (20.8%)	23.9±3.5	Quality 12/15 LoE[a] 2b
McGowan & Hoffman (2015)[29]	Observational	Race-day medical encounters. Data collected at the 2010-2013 races. 2010-2011: Data collected only at the race finish line. Medical encounters: 2012-2013: Data collected at all the race medical stations.	USA, California: Western States Endurance Run 161km (100miles) 5500m ascent, 7000m descent Max altitude: 2667m; Temperatures (min-max): 2010: 3-33 °C; 2011: 0-28 °C; 2012: 9-22 °C; 2013: 5-39 °C 30-hr cut of time, 24 aid stations	1563	2010: 43 ±10 (18-75); 2011: 43 ±10 (22-74); 2012: 42 ±10 (23-77); 2013: 42 ±10 (22-70)	2010 - Males: n=337 (79.7%) 2011- Males: n=305 (81.3%) 2012 - Males: n=313 (81.9%) 2013 - Males: n=306 (79.9%)	Not reported	Quality 8/15 LoE[a] 2b
Scheer & Murray (2011)[30]	Prospective observational	Clinical encounters; data were recorded on a standard form	Spain: 2010 Al Andalus Ultra Trail Ultramarathon 5-day stage race (219km)	69	Males: 46 (27-63) Females: 40 (25–50)	Males: n=48 (70%); Females: n= 21 (30%)	Not reported	Quality 10/15 LoE[a] 4
Scheer et al. (2014)[31]	Prospective observational	Data collected after each stage race through a direct interview technique using a standardised questionnaire on blisters	Spain: 2010 & 2011: Al Andalus Ultra Trail Ultramarathon 5-day stage race (219km) Temperature: 32-40 °C Humidity:32-40%.	50	Males: 40.4±8.3 Females: 40.4±7.5	Males: n=30 (60%) Females: n=20 (40%)	Males: 24.5±1.9; Females: 21.3±2.2	Quality 12/15 LoE[a] 2b
Vernillo et al. (2016)[32]	Cross-sectional	Medical encounter: Data recorded at the end of the race.	Trento, Italy: Vigolana Trail Run (65 km)	77	43.6 (± 10.9)	Males: n=64 (83%); Females: n=13 (17%)	Not reported	Quality 11/15 LoE[a] 4

a: Level of evidence
b: Multistage ultramarathon
c: Confidence interval

Table 2: Characteristics of the six studies that included training/race-related injury outcomes

Author(s) and publication year	Study design	Data collection	Setting	Number of participants (n)	Age (yrs)	Sex	BMI (kg/m^2)	Quality and LoE [a]
Babi et al. (2018)[21]	Retrospective cross-sectional	Questionnaire examining 5 psychological dimensions. Data collected at a race. Retrospectively inquired on an injury during the past 3 years	Spain: Cros de Muntanya Can Caralleu (7.5km & 15km); Borredà-Xtrail (11km, 28km & 44km); Zurich Marató de Barcelona (42km)	237 (Includes 45 from a non-trail race)	38.4±8.4 (17-60)	Male: n=183 (77.2%) Female: n=54 (22.8%)	N/A	Quality 8/15 LoE[a] 2b
Malliaropoulos et al. (2015)[8]	Cross-sectional	Self-reported injury questionnaire completed with the help of a physiotherapist	Greece: Training/racing	40	38.4 ± 8.7	Male: n=36 (90.0%) Female: n=4 (10.0%)	23.4±2.0	Quality 10/15 LoE[a] 2b
Hespanhol Junior et al. (2017)[26]	Prospective cohort	The Dutch version of the OSTRC [c] Questionnaire on Health Problems was used to collect self-reported injury and illness data biweekly over 6 months	Netherlands: Training/racing	228	All participants: 43.4 (95% CI[b]: 42.2-44.6) Male: 43.8 (42.4-45.2) Female: 42.4 (39.9-44.8)	Males: n=171 (75%) Females: n=57 (25%)	All: 22.6 (95%CI[b]: 22.3-22.8) Male: 23.0 (22.7-23.3) Female: 21.3 (20.9-21.8)	Quality 9/15 LoE[a] 2b
Matos et al. (2020) A[9]	Retrospective cross-sectional	Self-reported injury: Data collected via an online questionnaire during the previous 12 months (related to the year 2017)	Portugal: Training/racing Recreational runners	719	38.0±7.8	Male: n=529 (74%) Female: n=190 (26%)	Not reported	Quality 9/15 LoE[a] 2b
Matos et al. (2020) B[28]	Prospective cohort	Self-reported injury questionnaire. Workload-related data collected daily via GPS [d]	Portugal: Training towards 2018/2019 Portuguese trail running championships	25	36.23 ± 8.30	Males: n=25 (100%) Female: n=0 (0%)	Not reported	Quality 12/15 LoE[a] 1b
Viljoen et al. (2021)[33]	Retrospective cross-sectional	Self-reported injury questionnaire completed two weeks prior to race participation. Injury recorded retrospectively.	South Africa: Training towards SkyRun races (38km, 65km, 100km)	305	All: 38.3 (95% CI[b]: 37.4-39.2) Male: 38.7 (37.6-39.8) Female: 37.3 (35.7-38.8)	Males: n=213 (69.8%) Females: n=92 (30.2%)	All: 23.9 (95% CI[b]: 23.6-24.2) Male: 22.2 (21.7-22.6) Female: 24.6 (24.3-25.0)	Quality 12/15 LoE[a] 2b

a: Level of evidence
b: Confidence interval
c: Oslo Sports Trauma Research Centre
d: Global positioning system

3.2. Quality assessment and level of evidence

The mean score following the quality assessment of all studies was 10/15 (range 5-12) (table 1 and 2). Prior to consensus, the observed agreement for interrater reliability was 82.5% (Cohen's kappa=0.60). Items 11 and 12 that relates to the studies' external validity, and item 27 that assessed the power of each study, most frequently scored 0 ("no" or "unable to determine"). The individual item scores for each study are presented in the online supplementary appendix 3. The OCEBM level of evidence[36] was rated as 2b in 13 studies,[6-8 21 23 25-29 31 33 34] 4 in five studies,[11 22 24 30 32] and 1b in one study (table 1 and 2).[28] Prior to consensus, the observed agreement for interrater reliability was 89.5% (Cohen's kappa=0.75).

3.3. Trail running injury risk factors

A summary of significant and non-significant factors associated with either a higher or lower risk for injury among trail runners is presented in table 3. Among the 10 studies that investigated injury risk factors,[7-9 21 23 27 28 31 33 34] five studies used cross-sectional data[8 9 21 33 34] and three studies collected data prospectively with short follow-up periods (duration of the race).[7 27 31] Only one study used data collected in a prospective cohort study with a long follow-up period (52 weeks).[28] Four *race participation* studies[23 27 31 34] focussed on injury risk factors related to specific pathologies types only, namely muscle cramps[27] and dermatological injuries.[23 31 34] The most common injury risk factors investigated were age,[7 27 33 34] running experience (all running,[8 33] trail running,[33] and ultramarathon[27 31]), sex,[7 27 33] total weekly running distance,[8 27 33] BMI,[8 33] and running frequency (all running: days per week[8 33] and sessions per day;[8] trail running: days per week[33]).

There is level 2 evidence showing that neglecting a warm-up before running, ($r= 3.37$ $p<0.001$)[9] not using a specialised running plan ($p=0.0995$),[8] regular training on asphalt ($p=0.0004$),[8] double training sessions per day ($p=0.06$, hip joint specific),[8] higher running experience (>6 years) ($p=0.001$),[8] level A runner ($p=0.067$),[8] higher total propensity to sports accident questionnaire (PAD-22) score (sensation seeking, assumption of risk, perceived competence, perception of risk, and competitiveness) ($p<0.01$),[21] and physical labour occupations ($p=0.058$)[8] are associated with significantly higher injury risk.

Specifically for sunburn, more than three hours of training per day (OR: 1.01, 95% CI: 1.00-1.01, p=0.048), using shade as primary mode of sun protection (OR: 1.42, 95% CI: 1.00-2.01, p=0.048), younger age (OR: 0.98: 95% CI: 0.97-0.99, p<0.001), low skin phototypes (I and II)

(OR: 2.06, 95% CI: 1.35-3.14, p=0.001), and single relationship status (OR: 1.66, 95% CI: 1.45-2.41, p=0.007) are associated with a significant higher sunburn risk.[34]

A prior history of cramping (p<0.0001), higher levels for both post-race blood urea nitrogen (mg/dL) (p<0.05) and creatine kinase (IU/L) (p<0.001), and a slower race finishing time (p=0.048) were associated with a significantly higher risk for muscle cramping during a race.[27]

Level 2 evidence showed that a significant lower risk for injury was associated with higher running exposure time (r=-0.344, p<0.001),[9] a 10-yr increase in age (adjusted for sex and race hours) is associated with: 0.2 fewer (95% CI: -0.3 to -0.1) musculoskeletal (MSK) injuries and 0.4 fewer (95% CI: -0.6 to -0.1) skin disorders.[7] Sunscreen use (SPF>15) (OR: 1.59, 95% CI: 1.05-2.41, p=0.027) and being in shade at noon (OR 1.83, 95% CI: 1.14-2.96, p=0.013) were associated with a lower risk for sunburn.[34] Previous ultramarathon experience (r=-0.44, p<0.05) was associated with a lower risk for blisters.[31]

There is consistent evidence that suggests that running distance,[8 27 33] running frequency per week,[8 33] age,[7 27 33] sex,[7 27 33] and BMI[8 33] are not associated with injury risk in trail running.

Table 3: Summary of significant and non-significant factors associated with injury risk by the number of studies, quality, and level of evidence

Level of evidence		2b				2b 1b	Total studies (n)
	Injury risk factors	Higher injury risk (n; quality of evidence rating)		Lower injury risk (n; quality of evidence rating)		Non-significant: direction of the association is unknown (n; quality of evidence rating)	
		SIG [a]	Non-SIG [b]	SIG [a]	Non-SIG [b]		
Intrinsic	Age (younger) [c]	1 (10)[34]					1
	Prior history cramping in a race [d]	1 (13)[27]					1
	Higher post-race blood creatine kinase (UI/L) [d]	1 (13)[27]					1
	Higher post-race blood urea nitrogen (mg/dL) [d]	1 (13)[27]					1
	Higher total PAD-22 score [e]	1 (8)[21]					1
	Low phototypes (I and II) [c]	1 (10)[34]					1
	Level A runner [f]	1 (10)[8]					1
	Higher experienced runner [g]	1 (10)[8]				1 (12)[33]	2
	Higher post-race blood creatinine (mg/dL) [d]		1 (13)[27]				1
	Lower post-race serum sodium (mmol/L) [d]		1 (13)[27]				1
	Less ultramarathon running experience [d]		1 (13)[27]				1
	Higher weight loss during a race [d]		1 (13)[27]				1
	Age [d]		1 (13)[27]			1 (12)[33]	3
	Age (older)			1 (12)[7]			
	More ultramarathon running experience [h]			1 (12)[31]			1
	Trail running experience					1 (12)[33]	1
	Sex					3 (12-13)[7 27 33]	3
	BMI [i]					2 (10-12)[8 33]	2
	Knowledge on photoprotection [c]					1 (10)[34]	1
	Previous history of sunburn [c]					1 (10)[34]	1
Extrinsic	No warm-up before running	1 (9)[9]					1
	Not using a specialised running plan	1 (10)[8]					1
	Training on asphalt [j]	1 (10)[8]					1
	≥ 2 training sessions per day	1 (10)[8]					1
	≥ 3 h training per day [c]	1 (10)[34]					1
	Use of shade as sun protector [c]	1 (10)[34]					1
	Slower race finishing time [d]	1 (13)[27]					1
	Marital status: single [c]	1 (10)[34]					1
	Physical labour occupations	1 (10)[8]					1
	Less weekly running distance [d]		1 (13)[27]				1
	Fewer prior 161 km race finish [d]		1 (13)[27]				1
	Slower sodium intake rate (mg/h) during a race [d]		1 (13)[27]				1

	Use of sunscreen (SPF>15) [c]	1 (10)[34]			1
	Finding shade at noon [c]	1 (10)[34]			1
	Higher running exposure (time)	1 (9)[9]			1
	Type of stretching routine before running		1 (10)[8]		1
	Total weekly running distance		2 (10-12)[8 33]		2
	Running frequency per week		2 (10-12)[8 33]		2
	Trail running frequency per week		1 (12)[33]		1
	Running speed		1 (10)[8]		1
	Total weekly vertical gain during training		1 (12)[33]		1
	Type of running shoe		1 (10)[8]		1
	Prophylactic measures for blisters [h, k]		1 (12)[31]		1
	Alcohol use		1 (10)[8]		1
	Smoking		1 (10)[8]		1
	Previous highest running distance per week [d]		1 (13)[27]		1
	Previous longest furthest single run [d]		1 (13)[27]		1
	Prior unsuccessful 161 km race attempts [d]		1 (13)[27]		1
	Variations in training workload indices			1 (12)[28]	1

a: Statistically significant
b: Not statistically significant
c: Related to sunburn only
d: Related to muscle cramping only
e: Focus on five psychological factors, namely: sensation seeking, assumption of risk, perceived competence, perception of risk, and competitiveness
f: Mathematical algorithm to classify runners based on the difficulty level of previous races, performance, sex, and age
g: Significant injury risk shown for > 6 yrs
h: Related to blisters only
i: Body mass index
j: vs tartan or mountain surfaces
k: Type/fabric of socks, antiperspirants, talcum powder, lubricant to feet, and prophylactic taping

3.4. Epidemiology of injury

Among the 19 included studies, eight (42.1%) reported the incidence of injury,[7 9 11 24 26 30 32 33] 11 (57.9%) reported on the prevalence of injury,[8 9 23-28 31 33 34] while 18 (94.7%)[6-9 11 22-34] reported on the clinical characteristics of injury (online supplementary appendix 4).

3.4.1. Incidence and prevalence of injury

The overall reported incidence ranges were; 0.8 to 61.2 injuries/1000h of running,[7 33] 5.9 to 2762.1 injuries/1000 runners,[7 11] and only one reported the incidence/1000km ran as 1.2[24] (online supplementary appendix 4). The overall injury prevalence range was 1.3 to 90% (online supplementary appendix 4).[8 33]

3.4.2. Anatomical region and body area

Across all 18 studies that reported on the clinical characteristics of injury,[6-9 11 22-34] injuries of the lower limb were reported by 15 (83.3%) studies,[6-9 11 22-27 30-33] trunk injuries by 8 (44.4%),[7-9 11 25-27 33] and upper limb injuries by 6 (33.3%)[7 11 22 26 27 33] (table 4). The body regions most commonly reported on in all 18 studies[6-9 11 22-34] included the foot/toe (n=10, 55.6%),[6 8 9 11 22 23 26 31-33] ankle (n=9, 50.0%),[7 9 11 22 24-26 32 33] and hip/groin (n=9, 50.0%)[7-9 22 25-27 30 33] (table 4).

Table 4: Summary of the number of studies (n) reporting injury variables regarding anatomical region and body area

Anatomical region	Body area	All studies (n=19)	Training-related studies (n=6)	Race-related studies (n=13)		
				Sub-marathon [a] (n=1)	Marathon [b] (n=2)	Ultramarathon [c] (n=11)
Head and neck		5 [7 9 22 32 33]	2 [9 33]	-	1 [22]	2 [7 32]
	Head	3 [9 22 33]	2 [9 33]	-	1 [22]	-
	Neck	2 [9 32]	1 [9]	-	-	1 [32]
Upper Limb		6 [7 11 22 26 27 33]	2 [26 33]	1 [11]	2 [11 22]	2 [7 27]
	Shoulder	1 [33]	1 [33]	-	-	-
	Upper arm	1 [27]	-	-	-	1 [27]
	Forearm	1 [27]	-	-	-	1 [27]
	Wrist	2 [26 33]	1 [26]	-	-	-
	Hand	3 [22 27 33]	1 [33]	-	1 [22]	1 [27]
Trunk		8 [7-9 11 25-27 33]	4 [8 9 26 33]	1 [11]	1 [11]	3 [7 25 27]
	Chest	3 [9 26 33]	3 [9 26 33]	-	-	-
	Thoracic spine	1 [7]	-	-	-	1 [7]
	Lumbosacral	4 [8 9 26 33]	4 [8 9 26 33]	-	-	-
Lower Limb		15 [6-9 11 22-27 30-33]	4 [8 9 26 33]	1 [11]	2 [11 22]	9 [6 7 23-25 27 30-32]
	Hip/groin	9 [7-9 22 25-27 30 33]	4 [8 9 26 33]	-	1 [22]	4 [7 25 27 30]
	Thigh	6 [8 9 26 27 32 33]	4 [8 9 26 33]	-	-	2 [27 32]
	Knee	7 [8 9 11 25 26 32 33]	4 [8 9 26 33]	-	-	2 [25 32]
	Lower leg	8 [6 8 9 25-27 30 33]	4 [8 9 26 33]	-	-	4 [6 25 27 30]
	Ankle	9 [7 9 11 22 24-26 32 33]	3 [9 26 33]	-	1 [22]	4 [23 25 30 32]
	Foot/toe	10 [6 8 9 11 22 23 26 31-33]	4 [8 9 26 33]	-	1 [22]	4 [6 23 31 32]

a: < 42.2 km
b: 42.2 km
c: > 42.2 km

3.4.3. Tissue Type and pathology type

Among the 18 studies that reported on clinical characteristics of injury,[6-9 11 22-34] superficial tissue/skin injuries were noted in 13 (72.2%) studies,[1 6 9 22-26 28 31-34] muscle/tendon injuries in 8 (44.4%) studies,[8 9 22 26 27 29 32 33] and ligament/joint capsule injuries in 7 (38.9%) studies.[9 22 24 26 29 32 33] The specific injuries mostly included blisters (50.0%),[6 22-26 30-32] joint sprains (44.4%),[8 9 22 24 26 29 32 33] and tendinopathies (38.9%)[8 9 22 26 29 32 33] (table 5). Severe injuries in trail running include bone fractures[9 33] and concussions reported in 2 (11.1%) studies each.[29 33] Also, a dislocated metacarpophalangeal joint,[22] frost injury,[25] joint subluxation,[9] and tendon rupture[33] were reported in 1 (5.6%) study each.

Table 5: Summary of the number of studies (n) reporting injury variables regarding tissue and pathology type

Tissue type	Pathology type	All studies (n=19)	Training-related studies (n=6)	Race-related studies (n=13)		
				Sub-marathon [a] (n=1)	Marathon [b] (n=2)	Ultramarathon [c] (n=11)
Muscle/Tendon		8 [8 9 22 26 27 29 32 33]	4 [8 9 26 33]	-	1 [22]	3 [27 29 32]
	Muscle injury	5 [8 9 26 29 33]	4 [8 9 26 33]	-	-	1 [29]
	Muscle cramping	3 [27 29 32]	-	-	-	3 [27 29 32]
	Tendinopathy	7 [8 9 22 26 29 32 33]	4 [8 9 26 33]	-	1 [22]	2 [29 32]
	Tendon rupture	1 [33]	1 [33]	-	-	-
Nervous		4 [8 26 29 33]	3 [8 26 33]	-	-	1 [29]
	Brain/Concussion or Spinal cord injury	2 [29 33]	1 [33]	-	-	1 [29]
	Peripheral nerve injury	2 [8 33]	2 [8 33]	-	-	-
Bone		4 [8 9 26 33]	4 [8 9 26 33]	-	-	-
	Fracture	2 [9 33]	2 [9 33]	-	-	-
	Bone stress injury	3 [8 9 33]	3 [8 9 33]	-	-	-
Cartilage / Synovium / Bursa		4 [8 22 26 33]	3 [8 26 33]	-	1 [22]	-
	Cartilage injury	2 [8 33]	2 [8 33]	-	-	-
	Synovitis/Capsulitis	1 [33]	1 [33]	-	-	-
	Bursitis	2 [22 33]	1 [33]	-	1 [22]	-
Ligament/Joint capsule		7 [9 22 24 26 29 32 33]	3 [9 26 33]	-	1 [22]	3 [24 29 32]
	Joint sprain (ligament tear/acute instability episode)	8 [8 9 22 24 26 29 32 33]	4 [8 9 26 33]	-	1 [22]	3 [24 29 32]
	Chronic instability	1 [9]	1 [9]	-	-	-
Superficial tissues/skin		13 [6 9 22-26 28 30-34]	4 [9 26 28 33]	-	1 [22]	8 [6 23-25 30-32 34]
	Laceration	4 [22 24 32 33]	1 [33]	-	1 [22]	2 [24 32]
	Abrasion	6 [6 9 23-25 29]	1 [9]	-	-	5 [6 23-25 29]
	Blisters	9 [6 22-26 30-32]	1 [26]	-	1 [22]	7 [6 23-25 30-32]
	Contusion (superficial)	2 [9 29]	1 [9]	-	-	1 [29]
	Haematoma	2 [23 32]	-	-	-	2 [23 32]
	Frost injury	1 [25]	-	-	-	1 [25]
	Chafing	4 [9 23 30 32]	1 [9]	-	-	3 [23 30 32]
	Sunburn	3 [23 24 34]	-	-	-	3 [23 24 34]

a: < 42.2 km
b: 42.2 km
c: > 42.2 km

4. DISCUSSION

In this living systematic review, we identified intrinsic factors including higher running experience,[8] being a level A runner,[8] having a higher total PAD-22 questionnaire score,[21] and extrinsic factors including neglecting a warm-up,[9] not using a specialised running plan,[8] regular training on asphalt,[8] double training sessions per day,[8] and physical labour occupations[8] that are associated with significantly higher injury risk in trail running. A significantly higher risk of sunburn was associated with intrinsic factors of younger age and low skin phototypes, and external factors of more than three hours of training per day, using shade as the primary mode of sun protection, and single relationship status.[34] In addition, prior history of cramping, and higher levels of post-race blood urea nitrogen and creatine kinase, were intrinsic factors associated with a significantly higher risk for muscle cramping during a race.[27] A slower race finishing time was reported as an intrinsic risk factor associated with a significantly higher risk for muscle cramping.[27]

The injury incidence ranges from 0.8 to 61.2 injuries/1000h of running, and 5.9 to 2762.1 injuries/1000 runners, while prevalence of injury ranges between 1.3 to 90%. The clinical characteristics most commonly reported include: anatomical region (lower limb, trunk, upper limb), body area (foot/toe, ankle, hip/groin), tissue type (superficial tissue/skin, muscle/tendon, ligament/joint capsule), and pathology type (blisters, joint sprains, tendinopathies).

The higher number of injury-related studies included in this living systematic review (n=19), compared to a previous systematic review (n=11)[5] testifies of an emerging body of evidence pertaining to trail running injuries.

4.1. Significant injury risk factors in trail running

Having no previous running experience has moderate-quality evidence for being an associated injury risk factor in non-specific running-related injuries.[14] However, increased running experience was reported as a significant intrinsic injury risk factor in trail running.[8] In contrast, Scheer et al. (2014) reported that increased ultramarathon running experience had a significantly lower risk for dermatological injuries among trail runners,[31] while running experience (road and trail) were not associated with injury among South African trail runners.[33] The inconsistent evidence in trail running literature could be attributed to the variance in data collection methods (retrospective cross-sectional,[8 33] prospective with short follow-up period[31]) injury definitions (self-reported,[8 33] clinical assessment of blisters[31]) and pure race[31] versus

race/training participation.[8 33] Extrinsic factors such as not using a specialised running plan, regular training on asphalt, double training sessions per day, physical labour occupations, and an intrinsic factor of being a level A runner, were reported as significantly associated with injury risk among Greek trail runners.[8] No other studies have investigated these factors' association with injury in trail running. Considering the small sample size (n=40), self-reported injury data, potential recall bias, and retrospective cross-sectional study design, further investigation of these factors' association with injury is needed before generalisations to the global trail running community are made.

In agreement with various sports where the efficacy of neuromuscular warm-up strategies in lower limb injury prevention is seen,[37] neglecting warm-up before running was an extrinsic factor associated with a significantly higher injury risk among Portuguese runners.[9] However, for effective translation of these findings into clinical practice, clear details of these warm-up strategies should be disclosed.

One study analysed psychological dimensions' association with injury using the PAD-22 questionnaire.[21] None of the individual psychological dimensions were significantly associated with injury, however, a higher total PAD-22 questionnaire score (sensation seeking, assumption of risk, perceived competence, perception of risk, and competitiveness) was significantly associated with injury.[21] This finding should be extrapolated with caution considering the retrospective cross-sectional study design, predominantly male sample, specific Spanish population, and low quality of the study's evidence.[21] Nevertheless, these psychological dimensions have previously been shown to be associated with injury in other sports[38-40] and warrant further investigation into higher risk-taking behaviours among trail runners.

Hoffman and Steumplfe (2015) reported that intrinsic factors of a prior history of cramping, post-race muscle damage (higher blood urea nitrogen and creatine kinase) and an extrinsic factor of slower race finishing time, were significantly associated with muscle cramping in a 161km trail running event.[27] Similar results with regards to the previous history of muscle cramping and elevated biomarkers of muscle damage were reported among ultramarathon road runners.[27 41] However, a faster running time in road running (56 km)[41] was a significant injury risk factor for muscle cramping, compared to a slower time in trail running (161 km).[27] Progressive muscle fatigue heightens the risk for muscle cramping,[42] therefore, the contrasting finding could possibly be attributed to increased muscle fatigue resulting from different running surfaces (road vs trail), vertical gain/loss differences, longer race distances (161 vs 56

km), and duration of the Western States Endurance Run[27] versus the Two Oceans Marathon.[41] Muscle cramping is multifactorial in nature[43] and needs to be investigated in trail running specific settings as the current findings cannot be generalised to specific race participation within the global trail running population.

Two studies analysed risk factors specifically related to dermatological injuries.[31 34] Only one study reported significant associations for factors related to sunburn specifically.[34] Trail running is an outdoor sport[1] where the duration of sun exposure could vary substantially, depending on the race distance and time of day. Garcia-Malinis et al. (2020) reported multiple sunburn risk factors in trail running and highlighted how extrinsic factors such as sunscreen use and avoiding sun exposure at noon are associated with a significantly lower sunburn risk.[34] The acute skin effects of sunburn[44] can result in pain and discomfort during trail running participation, but of larger concern is the risk of developing skin cancer due to long term and severe sun exposure.[45]

Since most of the reported associated injury risk factors were determined using univariate analyses in cross-sectional study designs, we are cautious of elaborating on the clinical implications of these factors in the design of risk management strategies. As higher quality studies investigating risk factors over longer periods become available, future review updates will address the implication of modifiable and non-modifiable factors on risk management strategies.

4.2. Epidemiology of injury

The findings of this review regarding the injury incidence/prevalence and clinical characteristics of injury, need to be considered in the context of the various injury definitions used. Race participation studies mainly reported on medical encounters.[7 22-25 29 30 32] This could result in underestimating injury as not all race participants will report their injuries to event medical staff.[46] In contrast, all training exposure studies used self-reported injury data.[8 9 21 26 28 33] Even though self-reported injury allows for a broader range of injuries to be included,[20] the accuracy of data could be affected by recall bias and participant's limited understanding of pathology during self-diagnosis.

4.2.1. Incidence and prevalence

Studies included in this review showed a wide injury incidence range, especially a high upper limit (0.8 to 61.2 injuries/1000h running) compared to other running literature (weighted injury incidence: 7.7 to 17.8 injuries/1000h running).[47] A similar wide injury prevalence range was reported of 1.3 to 90%. The highest incidence and lowest prevalence of injury were reported among South African trail runners during a medical screening process two weeks before a high altitude mountain ultramarathon.[33] The high incidence of injury could be due to the high training loads involved in preparation for the race. These results need to be interpreted in context of the retrospective cross-sectional study design used to collect data dating back 12 months before the race and potential recall bias involved in self-reported injury data.[33] Runners' fears for being medically disqualified before the race[33] may also have contributed to the lower reported injury prevalence. Only two trail running studies used prospective study designs to collect data over longer periods and reported injury incidence (10.7 injuries/1000h running)[26] and prevalence values (22.4-52%)[26 28] concurring with other running literature.[13 47]

4.2.2. Clinical characteristics

The lower limb is still the most commonly reported anatomical region of injury in trail running literature (83.3% of studies) and is in agreement with a previous review.[5] Notably, a growing number of studies indicated that the trunk,[7-9 11 25-27 33] upper limb,[7 11 22 26 27 33] and head/neck[7 9 22 32 33] are injured anatomical regions. Although less frequent, clinicians need to consider injuries such as finger joint dislocations,[22] upper limb/hand lacerations,[22] lumbar/cervical spine strains,[7-9 26] and concussions[29 33] during planning for optimal medical provision.

The foot/toe was previously and is currently still reported as the most common body region of injury across all trail running studies.[5] This finding may be supported by the fact that the most common injured tissue type reported was skin, specifically blistering resulting from footwear due to cyclic shearing forces typically experienced during ultramarathons.[48] Our review also included a high number of studies investigating race-related injury outcomes related to ultramarathon distances[6 7 23-25 27 29-32 34] and one study investigated foot blisters specifically.[31]

In this review, the ankle is more commonly reported across trail running injury studies as opposed to the knee.[5] The commonly occurring acute ankle sprains[26 32] due to variation of uneven running surfaces synonymous with trail running could explain this discrepancy/change in finding. This finding is further supported by ligament/joint capsule and joint sprains being

among the top three most commonly reported tissue and pathology types reported among all included studies.

4.3. Clinical implications

The clinical implications of this review are restricted by the limited research and poor quality of available evidence in the field. In the absence of quality research evidence, a proposed solution is to make use of clinical practice guidelines or expert opinion to guide clinical decision making.[49] The only clinical practice guidelines on reducing the risk for health problems in trail running focused on medical support at ultra-endurance races in remote regions.[10] The authors mainly addressed guidelines for primary medical care at races but also highlighted the importance of risk reduction strategies such as pre-race runner education, pre-race medical screening, and considerations for cancelling races in the presence of extreme environmental conditions (floods, fire, heavy snow or rainfall).[10] Clear guidance on what runners should be educated on, or the specific factors to consider during pre-race medical screening is unclear. As this living systematic review matures, we expect to provide the clinician with evidence-based guidance on injury risk factors to consider during runner education and medical screening either pre-race or during training.

4.4. Limitations

Studies included in this review had a relatively low mean quality score (66.7%). This is attributed to the lack of sample size calculations, which negatively affected the power of included studies. In the majority of studies, the external validity was threatened due to uncertainty regarding whether participants were recruited from a representative population.

Significant injury risk factors are mainly reported in individual studies and not replicated across various settings. The majority of studies used univariate analyses to investigate risk factors' association with injury. It is unlikely that the injury risk in trail running can only be assigned to a single factor, which further ignores the complex interaction between different factors involved in sports injuries.[50] Not all injury risk areas have yet been studied. Multiple studies did not state the direction of the association for non-significant injury risk factors.[7 8 27 28 31 33 34] Some factors might still have clinical relevance despite not meeting the required alpha-level for statistical significance. The majority (80.8%) of participants were male, and risk factors associated with specific injuries among females[51] have not been investigated.

Mainly *race participation studies*[6 7 11 22-25 27 29-32 34] were included in this review which largely focussed on ultramarathons.[6 7 23-25 27 29-32 34] This may have skewed the findings of the foot as the most commonly injured body region and superficial skin as the most commonly reported injured tissue type most likely stemmed from shoe blister formation. Furthermore, one study only reported on injury outcomes related to blisters of the feet.[31] All *training/race participation* studies used self-reported injury data,[8 9 21 26 28 33] subjected to recall bias. Not all studies gave clear indications of the frequencies of injuries under the categories within clinical characteristics.

4.5. Recommendations

Higher quality studies are required to further investigate the significance of the current injury risk factors available in the literature. More risk factors also need to be investigated as pointed out in a recent position statement.[1] These include race setting, distance, elevation changes, min/max temperatures, humidity, and running surfaces.[1]. To address current insufficient power among trail running studies, researchers are encouraged to report sample size calculations where appropriate. Prospective cohort studies with longer follow-up periods are needed to investigate the temporality of risk factors associated with injury. The casual nature of these factors should be investigated in randomised controlled trials. Multivariate risk factor analyses should be used where applicable to account for the interaction of different factors in sports-related injuries. Attempts to account for the complexity of trail running injury requires moving away from discrete risk factor identification and towards risk pattern recognition.[50] Investigation into the current known significant injury risk factors is needed to evaluate whether these results can be reproduced and are applicable among different trail running populations. Risk factors among shorter distance trail races and female runners should also be investigated.

5. CONCLUSION

There is a dearth of studies investigating injury risk factors in trail running. These studies predominantly focus on the reductionist paradigm, identifying linear relationships of isolated factors associated with injury using univariate analyses. Our review found eight intrinsic and nine extrinsic risk factors associated with injury in trail running. The lower limb is the most commonly injured anatomical region, specifically the foot/toe, ankle and hip/groin. Advances in trail running injury research focussed on injury risk factors associated with specific injury

profiles will assist in the design and implementation of future injury risk management strategies for safer trail running participation.

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CHAPTER 7

General discussion

The structure of this general discussion chapter is as follows: 1) discuss the main findings of this thesis in the context of the specified research aims and objectives and other relevant literature, 2) discuss how the developed trail running injury screening instrument (TRISI) could contribute to injury risk management in trail running, 3) discuss considerations for keeping the TRISI relevant in future, 4) highlight the limitations of this thesis, and discuss the practical implications of the main findings in the context of the limitations, and 5) guide future research directions.

1. MAIN FINDINGS

In this discussion of the main findings, one should acknowledge various factors that could influence the discrepancies seen in the findings among various studies. Factors such as different injury definitions, study populations, study designs, etc., are well reported in trail running literature. However, factors surrounding the studies' setting and related trail running exposure have been largely neglected in methodological descriptions of trail running literature. In race participation studies, we cannot assume that two races hosted in the same country and similar distances will result in similar running exposure. Especially in trail running, we need to consider the effect of elevation gain, average running altitude, type of terrain, etc. These factors have an important effect on ultimate running exposure. Similar in prospective studies that include training-related injury data. By only stating the nationality of the population under investigation and running exposure in terms of the number of sessions, the reader/clinician/researcher is left floundering on how generalisable the findings are to their context, considering the specific geographical factors (terrain, altitude, elevation gain etc.)? I acknowledge that even though these geographical variables seem to be relevant from a clinical perspective, these variables have yet to be associated with injury in the literature. Nevertheless, these variables have also not been extensively investigated in the literature. In summary, trail running has unique variables to consider when interpreting a study's findings and discrepancies between studies. How and if these variables contribute to injury in trail running is not yet known and should be investigated in future injury research.

1.1. Epidemiology of injury in trail running

1.1.1 Incidence and prevalence of all injury

To my knowledge, I performed the first systematic review[1] (*Chapter 2*) that summarised research evidence regarding the epidemiology of injury in trail running. An incidence range with an abnormally high upper limit of 1.6-4285 injuries per 1000 h of running was initially reported in the review.[1] This high incidence of injury raised concerns regarding the health benefits vs injury risk involved in trail running. However, the high upper limit was an outlier reported in a single cross-sectional study among Italian trail runners.[2] Later, Vernillo et al. (2016) published an erratum (after the review was published) to rectify their calculation error made and reported an updated incidence of 61.2 injuries per 1000 h of running.[2] To ensure accurate reporting in the systematic review (*Chapter 2*), an update was published to reflect the corrected incidence rate of Vernillo et al. (2016).[2] An incidence of 61.2 injuries per 1000 h of running is still high in the context of other trail running studies. This could result from recording injuries directly at the finish line of an ultra-distance race by asking each participant about their injuries sustained. It is reasonable to believe that runners should have some form of physical discomfort due to repetitive strain in an ultra-distance event that could have hyperinflated the incidence of injury.[3] Despite the high incidence of injury, all musculoskeletal injuries were minor, and participants could safely complete the race.[2] The review highlighted that most studies reported injury data related to ultra-distance race participation with limited prospective studies that included training-related injury data. Short distance trail running was also neglected in the literature.[1] These research gaps prompted us to conduct original research to work towards addressing the gaps in the literature.

Chapter 3 reported an injury rate of 19.6 running-related injuries (RRI) per 1000 h of running and a mean RRI prevalence of 12.3%.[4] Due to the absence of prospective studies, the findings are difficult to compare. Hespanhol et al. (2017) is currently the only other study that prospectively investigated the epidemiology of injury among trail runners.[5] They investigated a Dutch trail running population and found a lower injury rate and higher injury prevalence than our findings. Considering the different injury definitions, classification of trail runners, trail running exposure, and geographical regions of running, these differences in findings could be related to many factors. Furthermore, injury profiles in running differ between ultramarathon and non-ultramarathon runners.[6] In both *Chapter 3* of this thesis and the study[4] of Hespanhol et al. (2017),[5] it was not specified which percentage of study participants were ultramarathon, marathon, or short-distance trail runners.

Chapter 4 analysed an existing dataset based on injury among shorter distance trail runners (< 25 km).[7] Data was collected using a pre-race medical screening questionnaire, and a retrospective overall injury prevalence of 12% was reported.[7] A higher injury prevalence of 31% was reported among a European shorter distance trail running population.[8] In my study, participants were only questioned on gradual onset running-related injury (GORRI), which could have resulted in the lower injury prevalence reported.[7] From the limited available research evidence, it seems as if sudden onset injuries also occur among trail runners[4], and further investigation is warranted.

1.1.2. Gradual vs sudden onset injury in trail running

The 2020 International Olympic Committee's (IOC) consensus statement on methods for recording and reporting epidemiological data on injury and illness in sport, highlighted the challenge in the dichotomy between acute vs overuse injury, and gradual vs sudden onset injury.[9] In this thesis, I used the terminology of gradual onset injury representing a gradual accumulation of lower energy transfer and sudden onset for instant transfer of large kinetic energy resulting in injury.[9] In the systematic reviews included in this thesis (*Chapters 2* and *6*)[1 10], I had to report on injury as defined in the included studies.

Running-related injury literature has largely reported gradual onset injury among runners, and multiple studies only focused on gradual onset (overuse) injury in running.[11-13] The systematic review (*Chapter 2*) highlighted how injuries reported as "acute" also occur in trail running.[1] Even though less common, severe sudden onset injuries like concussions, fractures, joint dislocations/subluxations, and tendon ruptures were reported among trail runners.[10] At the time, trail running injury literature largely consisted of cross-sectional studies focused on race participation.[1] These findings prompted the prospective investigation of the injury incidence of sudden vs gradual onset injury while including training exposure (*Chapter 3*).[4]

Chapter 3 reported a non-significant higher mean prevalence for sudden onset RRIs than gradual onset RRIs.[4] The findings did not correlate with those of Hespanhol et al. (2017), who showed a near four times higher injury prevalence for overuse (gradual onset) vs acute (sudden onset) injuries among Dutch trail runners.[5] Multiple factors need to be taken into account when interpreting these findings. Firstly, both studies had similar trail running exposure in weekly training sessions and running distance. However, the geographical factors contributing to specific trail running exposure were not reported. The geographical characteristics of The Netherlands vs South Africa could have played a role in the onset of injury, considering how

different uneven running surfaces could contribute to the risk of falling, acute joint instability episodes, etc. Furthermore, our classification of injury could have been misinterpreted by participants. An injury could be due to a gradual accumulation of lower energy transfer over time (such as tendinopathy) but present with an acute onset of symptoms later during normal loading of the injured tissue.

The 2020 IOC consensus statement advised improved reporting that classifies injury as acute sudden onset, repetitive sudden onset, and repetitive gradual onset injuries.[9] However, to classify injuries in this manner, a form of clinical assessment will be required, which is impossible when working with self-reported injury data. We should attempt following trail runners over longer periods using clinical assessments to classify injury in the future. This will require more financial resources to support larger research teams.

The findings from *Chapter 4* did not help provide further insight into this topic of discussion. A dataset based on self-reported injury data-focused purely on gradual onset injury was analysed,[7] which eliminated the possibility of comparing the prevalence of gradual vs sudden onset injuries.

1.1.3. Injury among male vs female trail runners

The living systematic review shows that currently, women represent only 15.8% of all participants in studies that investigated the epidemiology of injury or associated injury risk factors in trail running.[10] Furthermore, few studies attempted to compare injury rates between males and females. *Chapter 3* reported a significantly higher injury rate for males (12.7 RRIs per 1000 h or running) than females (3.1 RRIs per 1000 h of running).[4] However, care should be taken when interpreting the findings. Only 26.7% of my study sample were females, which affected the reliability of the findings. I acknowledge a recent systematic review with meta-analysis and meta-regression that showed no difference in overall injury rates between male and female runners for injuries in any form of running.[14] However, we cannot assume that this will be the case in trail running, and further investigation is needed. In all forms of running, females showed a higher risk for injury, specifically in shorter running distances.[14] My injury findings among shorter distance trail runners showed no difference in injury prevalence between males and females.[7]

1.1.4. Clinical characteristics of trail running injury

Current literature most commonly reports the lower limb as the injured anatomical region, affecting the foot/toe, followed by the ankle and hip/groin. These findings are mainly based on race participation studies with ultra-distance running exposure.[10] In *Chapters 3* and *4*, similar results were found in the lower limb being the most common anatomical region of injury. The main injured body regions were the knee, followed by shin/lower leg in both chapters, with foot/toes in *Chapter 3* and thigh in *Chapter 4* as the third most injured body region. [4 7] The foot/toe as the most injured regions should be evaluated in the context of mainly included ultra-endurance events in current literature. Ultra-endurance events expose runners' feet to repetitive cyclic shearing forces from shoes that commonly result in blisters. With the foot/toe and blisters specifically being mostly involved in trail running injury,[10] we need to consider whether the injury profile will change if more studies focus on shorter running distances and investigate injury prospectively, including training exposure.

We need to consider that injuries are not isolated to the lower limb in trail running. Even though less common, the upper limb, trunk, and head/neck are also reported as injured anatomical regions. Furthermore, with joint sprains, contusions, concussions, lacerations, and fractures reported as pathology types, it is reasonable to believe that the running surface could expose trail runners to acute joint instability episodes and trauma due to falling. However, there is a lack of published data on the mechanisms of injury involved in these sudden onset injuries. Race day medical teams need to prepare for the possibility of sudden onset injuries in remote settings where races are usually hosted. At the same time, trail runners could benefit from carrying basic first aid kits in their running packs to assist themselves or fellow injured runners.

The main findings discussed in *Sections 1.1* addressed my research *Objectives 1* and *4* of *Phase 1*.

1.2. Associated injury risk factors in trail running

Working towards developing a TRISI based on associated injury risk factors in trail running, I experienced challenges due to limited research evidence in the field. Therefore, I first aimed to add to the body of knowledge by conducting original research in investigating a variety of injury risk factors, including trail running specific factors such as elevation gain and trail running surface (*Chapter 3*)[4] and investigating injury risk factors among shorter distance trail runners (*Chapter 4*).[7] I also questioned trail runners on which factors they perceive to be

associated with a higher risk of injury and performed a literature search to identify injury risk factors in general running (*Chapter 5*). To keep the TRISI updated, the first living systematic review of injury risk factors in trail running (*Chapter 6*).[10] Figure 1 is a schematic illustration of my contribution to the knowledge gap concerning injury risk factors in trail running.

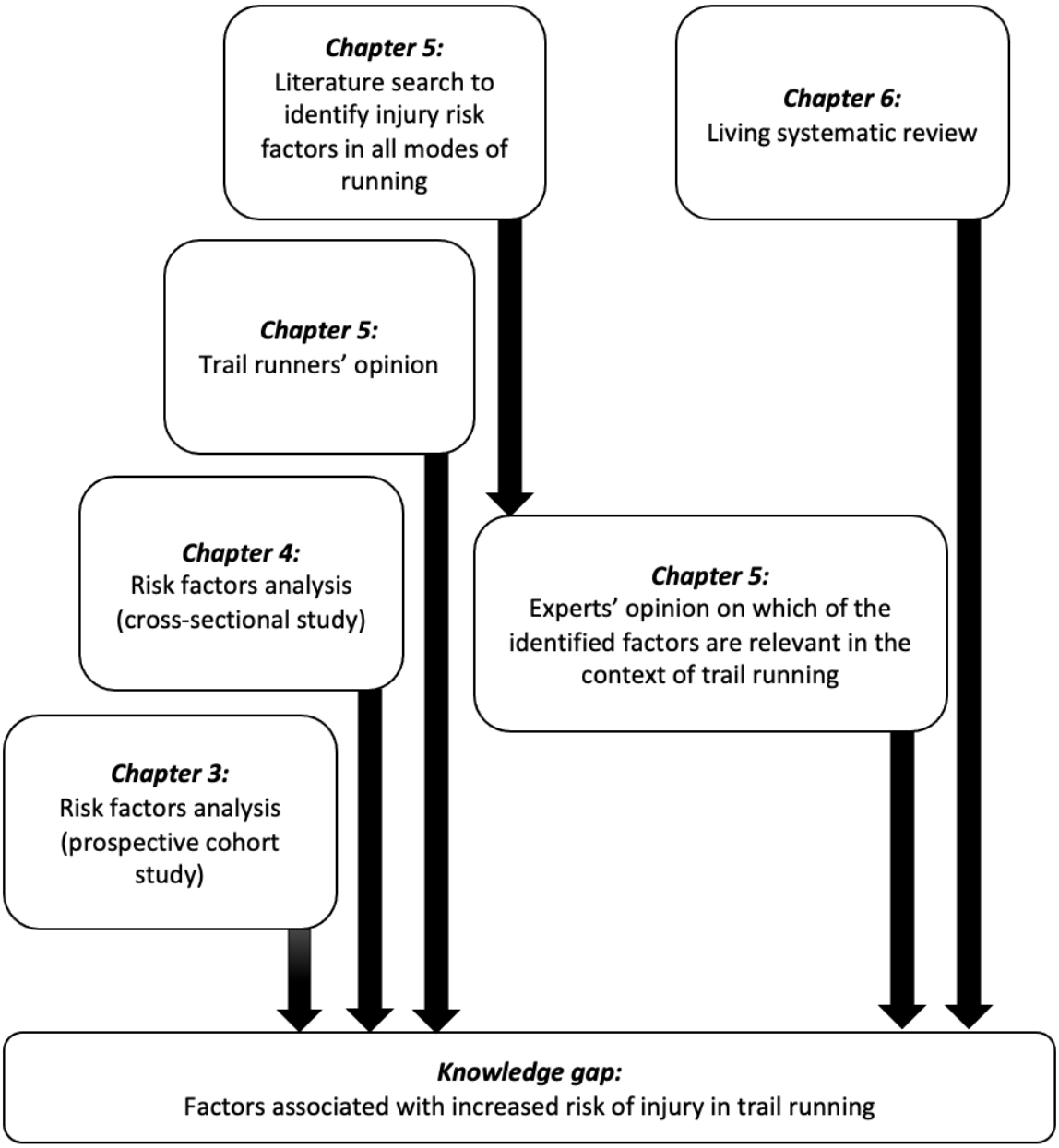

Figure 1: The contribution of this thesis towards closing the knowledge gap with regards to injury risk factors in trail running

1.2.1. Original research investigating injury risk factors in trail running

Chapter 3 reported a history of previous RRI as an independent risk factor for RRIs among trail runners.[4] Previous injury as a risk factor has been associated with injury in other sports,[15] [16] but was not previously investigated in trail running. Numerous factors could affect this, like whether the runner returned to sport too early, the rehabilitation plan was adequate to restore previous function and tissue loading capacity optimally, etc.

Chapter 3 also highlighted how having a chronic disease is an independent injury risk factor.[4] This is in agreement with findings among road-based endurance runners.[17] In literature, various chronic diseases have shown associations with an increased risk for injury, especially gradual onset injury.[18-22] In trail running, I initially noted the association of chronic disease with an injury during the analysis of a dataset consisting of retrospective, cross-sectional data.[7] This prompted an investigation into chronic disease as an injury risk factor prospectively. However, the association of chronic disease with an injury needs to be interpreted with caution. Currently, no available research evidence can adequately describe a potential physiological reason that relates the actual chronic disease to an increased risk for injury. We have evidence that certain medications used in treating chronic disease are associated with injury.[23-29] For example, statins,[24 27] fluoroquinolones,[26] corticosteroids,[23] aromatase-inhibitors,[29] and isotretinoin[25] are associated with drug-induced tendinopathies. Corticosteroid use is associated with a higher risk for tendon ruptures[23] and osteoporosis.[28] This raises the question of whether it is not the role of medication exposing runners to a higher risk for injury and not the chronic disease itself. In *Chapter 4,* I report that a higher number of chronic diseases is associated with injury in a dose-dependent fashion.[7] Here again, we need to question the medications' interaction in the presence of multiple chronic diseases. Increased tendon toxicity was observed when certain medications interact[30], and combining certain medications increase the risk of developing toxic tendinopathy.[31] This could explain why more chronic diseases were associated with a higher risk for GORRIs.[7] To investigate whether it is the chronic disease itself that exposes the runner to a higher risk of injury, researchers will either have to 1) investigate runners with chronic disease not using medication or 2) ask runners to stop using their medication for the duration of a research study. The challenge with option 1 is that most chronic diseases require medication to control the disease safely. If a research participant states on a questionnaire that they have a chronic disease, then that participant was most likely diagnosed by a medical doctor and educated on the importance of using the specific prescribed medication. It is unlikely that research participants having a chronic disease will not be using medication. Option 2 breaches

research ethical conduct. The risk associated with not using medication to safely control disease far outweighs the benefit of exploring the associations of the chronic disease itself with the risk of injury. For now, trail runners and clinicians need to note that having a chronic disease, most likely due to the medication used to control the disease, is associated with a higher risk for injury. Future studies might explore which type of injuries a runner with a chronic disease sustain. This might further support the argument that medication use is potentially the reason for the higher injury risk noted.

Having a history of allergies was also shown to be associated with GORRIs in *Chapter 4*.[7] A history of allergies is common among endurance athlete,[32 33] therefore, careful consideration of the potential reasons for the association of allergies with GORRIs is needed. Like the discussion on chronic disease, we should question whether allergies themselves have an underlying physiological reason for increasing the risk of GORRIs or the medications used to treat allergies that contribute to the injury risk. We currently have no evidence supporting underlying physiological contributions to the association, but the medication used for allergies might contribute. For example, anti-histamines have side effects, which include fatigue and drowsiness.[34] We can argue that acute fatigue will affect motor control and proprioception, which may increase injury risk.[35] However, I had no information on whether these participants were actively using medication during training or racing. The relationship between allergies and injury risk should be further explored in more controlled settings.

Among shorter distance trail runners, entering for the longer race distance (22km vs 10km) was found to be an independent injury risk factor.[7] Elaborating on potential reasons for this finding is challenging, as I didn't have access to these race entrants' specific training data. In clinical practice it is noted that trail runners participating in half-marathon trail distance are often those making the transition from road to trail running or from a 10km trail to a 20+ km trail, which both involve an increase in training load to prepare optimally. This finding will have to be further investigated, ideally collecting training data prospectively leading up to the race to avoid recall bias. At this stage, this finding is not particularly useful for clinicians when designing individualised risk management strategies for trail runners, as it relates to a very specific population training towards a very specific race. However, it can still be useful for race-day medical staff. Previous injury is associated with a higher risk for injury.[4 15 16] Therefore, the race entrants reporting being injured 12 months before race participation could be at higher risk to sustain an injury on race day. Race-day medical staff at the Two Oceans

trail runs could prepare accordingly by ensuring more medical staff is assigned to the 22km route, especially in challenging medical evacuation areas.

1.2.2. Trail runners' perception of injury risk factors

Trail runners were asked: "In your opinion, what factors increase your risk for getting injured during trail running (training or racing)?" (*Chapter 5*). The majority of trail runners reported injury risk factors in the category of training factors (80.0%), followed by behavioural factors (12.4%), equipment use (2.8%), nutrition (2.1%) demographic profile (1.4%), injury history (0.7%) and medication use (0.7%). With the limited and weak evidence currently available regarding injury risk factors in trail running, we need to include trail runners' input. These runners might provide valuable input about immediate injury risk management and future research directions. Even though trail runners perceive training factors to have the largest contribution to the injury, limited studies specifically investigated factors in this domain. Planning future studies regarding injury risk in trail running could benefit from the input of trail runners participating in the field.

1.2.3. Literature search

Due to the limited available evidence on injury risk factors in trail running, I decided to perform a literature search to identify additional injury risk factors in general running. I acknowledge that unique risk factors to trail need to be explored, like elevation gain, running surface, etc. However, certain factors may relate to trail running and road running, such as previous injury history, weekly running distance, etc. Therefore, it was deemed fitting to include injury risk factors of other running forms. It is important to note that a panel of experts determined the relevance of these identified injury risk factors in a trail running context.

1.2.4. Other risk factors in trail running literature – living systematic review

Chapter 6 presented the results of the first publication of the living systematic review that primarily focuses on injury risk in trail running.[10] A total of 17 factors associated with injury were identified in 10 different studies. Before these factors can be implemented into individualised injury risk management strategies, clinicians need to understand the limitations in the current included studies of the living systematic review. Most studies reported on significant associations with injury determined this through univariate analysis only, which largely ignores the complexity of sports injuries.[36] I acknowledge that multivariate analyses

will not completely solve the issue as a multivariate model still only includes a certain number of factors. However, it does provide stronger evidence for the estimated injury risk associated with certain factors. Most participants included in the review were men, and the estimated injury risk might differ between male and female participants. For example, higher injury rates for bone stress injuries have been shown among women compared to men.[14] As the livening systematic review matures over the five-year review period, I hope to report on stronger evidence relating to injury risk factors in trail running.

The main findings discussed in *Sections 1.2* addressed my research *Objectives 2* and *4* of *Phase 1*.

1.3. Development of a trail running injury screening instrument (TRISI)

After identification of associated injury risk factors related to trail running from original research (*Chapters 3* and *4*) and a literature search (*Chapter 5*), I made use of expert input to develop the TRISI (*Chapter 6*) using the methodology of human judgement modelling.[37] Human judgement modelling is used in cases where well-understood conditions don't present themselves with a single measurable attribute but as a phenomenon having multiple attributes.[37] This is the case with injury and the associated risk thereof in trail running. Experts in the field could guide the multiple attributes of injury in trail running by understanding the phenomenon.

The selection of 'experts' is very important as they are responsible for deciding which factors are relevant and determining the contribution of each factor to injury risk. I based my selection of experts on the larger aim of the screening instrument. In this case, I wanted to develop a tool to assist clinicians in clinical decision-making regarding injury risk management in trail running. For this purpose, the ideal expert would be a combination of 1) a clinician regularly working with trail runners in injury assessment, treatment, rehabilitation, and injury risk management, 2) an experienced researcher in the field of sports injury risk management, 3) a trail running coach that understands the training requirements for various trail running demands and has the insight to what training errors to avoid relating to injury, and 4) trail runner participating in a variety of race and training distance in multiple natural environments to have first-hand experiences of the demands of trail running. In short, I could not find an expert meeting all these specific requirements. Therefore, I ensured that I selected panellists so that the larger panel covered all these mentioned characteristics. This composition of the panels further justifies why a more common methodology such as the Delphi method was not used. The Delphi method requires consensus among all panellists. However, I included a variety of

experts from various professions that will unlikely reach a consensus. For example, a trail runner employed as an accountant might not agree that certain biomechanical factors contribute to the injury due to the panellist's lack of knowledge in the field of human movement. But, through human judgement modelling, every panellist's input is considered in the context of all other panellists.[37]

The first expert panel narrowed down a list of 77 potential injury risk factors to 29. Three factors were excluded because expensive equipment that is not readily available is needed to test these specific factors. A second panel provided weightings to each factor compared to all other injury risk factors. The second panel also provided weightings to each injury risk factor Likert Scale point to indicate increased injury risk. The final TRISI consists of 26 injury risk factors and covers the 10 domains of training, running equipment, demographics, previous injury, behavioural, psychological, nutrition, chronic disease, physiological, and biomechanical factors (*Chapter 5*).

The TRISI is the first clinical decision aid developed in trail-running injury screening. The main findings discussed in *Sections 1.3* addressed my research *Objectives 1 to 3* of *Phase 2*.

2. TRISI'S POTENTIAL IN INJURY RISK MANAGEMENT IN TRAIL RUNNING

In trail running, there is limited literature that involves expert guidance on injury risk management. Hoffman et al. (2014) provided expert guidance on providing medical services at ultra-endurance races.[38] These authors addressed factors to consider during pre-race medical planning and special medical considerations, including pre-race runner education and clearance, considerations for cancellation of an event in extreme weather conditions, etc. However, the detail of which factors to consider during runner education and pre-race medical screening is unclear. From an injury perspective, the TRISI could guide clinicians on factors to consider as part of runner education and screening and which factors are of higher priority. Injury screening using the TRISI in the two weeks before a race should be used to guide medical staff on which runners are at higher risk for injury. While if regular injury screening in the months leading up to a race is done, these factors could be addressed through injury risk management strategies, including runner education.

On purpose, I stayed away from developing an injury screening instrument that attempts to establish cut-off scores for higher vs lower risk categories. Sports injuries are complex, with multiple factors contributing to injury.[36] Even though many factors were included covering 10

domains of injury risk, there might be important injury risk factors that the TRISI omitted. Therefore, I advocate active involvement of the clinician where the TRISI is incorporated in an injury assessment or screening.

Regular screening using the TRISI is advised. The temporality of injury risk factors[36] emphasises the need to regularly individualise and adjust injury risk management strategies based on the new findings. A once-off screening will provide a good baseline for implementing a risk management strategy. However, the strategy might not be relevant in the coming months based on how the factors reacted to the previous interventions.

Lastly, an implementation and feasibility trial should be conducted. The perfect instrument can be developed, but if it has a poor user experience and usability, it will not be taken up in larger clinical practice and will have no effect in aiding clinicians in designing injury risk management strategies.

In summary, I put forward an injury screening instrument designed specifically for injury risk management in trail running based on expert input. Injury screening should be done regularly by a clinician. The feasibility of TRISI should be determined before implementation in mainstream clinical practice.

3. UPDATING THE TRISI

The TRISI is based on injury risk factors relevant to trail running by experts. For the TRISI to stay relevant in future, it will need to be updated. This requires staying up to date with the current literature on injury risk factors in trail running. For this purpose, a living systematic review was initiated to identify associated injury factors regularly over five years.[10] The second updated search have already been completed and the updated findings will be presented on the designated website (http://www.slhamsterdam.com/lsr-trailrunning) before the 1st of July 2022.

As we don't have strong evidence regarding the currently identified factors' association with injury, we will need input from experts on whether these factors are, in fact, relevant in trail running. Therefore, I advise evaluating new factors and re-evaluating previously included factors by experts within the next two years.

The main findings discussed in Sections 3 addressed my research *Objectives 1* and *2* of *Phase 3*.

4. LIMITATIONS

In *Chapter 2*, a systematic review of injury and illness epidemiology in trail running was conducted.[1] In hindsight, I could have included injury risk factors as part of the review and excluded illness. The living systematic review (*Chapter 6*), which was conducted only after I started developing the TRISI, showed weak evidence for the association of any factor with injury.[10] But, it would have been valuable for the first expert panel (*Chapter 5*) to consider still the injury risk factors reported in the living systematic review and their potential relevance in trail running. My main reason for conducting the living systematic review was to stay updated with current literature on injury risk factors in trail running to keep the TRISI updated as new stronger evidence became available. However, it could have served a larger purpose in developing TRISI as well.

Studies included in *Chapter 2* were limited to English and French languages.[1] At the stage, I could only include languages based on the language proficiency among the author group, which raised the concern of potentially missing relevant articles. Later in the living systematic review[10], a larger author group from various countries were involved and I could then add studies in Spanish and Portuguese. After I expanded the language inclusion criteria, one relevant study published in Spanish was identified.[39] However, this study would not have been identified in the original review (*Chapter 2*) due to the more recent publication date.

In *Chapters 3* and *4,* self-reported injury data was used. We can assume that runners should know the anatomical regions and even body areas of injury. But the findings regarding injured tissue and pathology type should be cautioned as most runners self-diagnosed, and I had no access to the clinical record to confirm reported injuries diagnosed by medical professionals.

Recall bias could have affected *Chapter 4*, as runners were questioned on their injury history, training variables, etc., up to 12 months prior. Considering the fluctuations in a runner's normal training schedule (planned in a training programme or unplanned due to demanding work schedules, etc.), it is unlikely that accurate training data were collected. Even though participants were followed more frequently in *Chapter 3*, recall bias could still be present over two weeks.

One should interpret all training data with caution in the original research papers (*Chapters 3* and *4*) of this thesis. I could not confirm whether participants reported their training variables based on accurate global positioning system (GPS) data or made estimated guesses which could have been influenced by what they recalled from recent weeks. I acknowledge that not all GPS

devices record exact accurate data in terms of running distance.[40] However, it is reasonable to believe that a GPS will at least provide more accurate data compared to a participant's estimation of running exposure over the past two[4] weeks or 12 months.[7]

As the onset of injury was not confirmed through clinical assessment in *Chapter 3*, tendinopathy with an underlying origin of low energy transfer over time could have been reported as a sudden onset injury when the patient first experienced symptoms. In the light of self-reported injury data, the finding of a higher prevalence for sudden vs gradual onset injury should be interpreted with caution.

In current literature regarding injury in trail running (*Chapter 6*) and my original research papers (*Chapter 3* and *4*), women are underrepresented, with transgender participants not being investigated. With women being exposed to unique injury risk factors due to menstrual cycles,[41] we might see a different injury profile or associated risk factors than what is currently reported. Similarly, the effect of hormonal therapy in transgender participants might contribute a unique set of factors to consider in injury risk management.[42] Currently, the findings in this thesis need to be interpreted in the context of most men being investigated.

One should be cautious when extrapolating the findings of *Chapters 3* and *4* to an international trail running population. These participants were mainly exposed to trail running environments in South Africa, and individual training session exposures were not recorded. Furthermore, I could not determine whether the study sample in *Chapter 3* was representative of the South African trail running population. Therefore, caution should also be taken when extrapolating the findings directly to South African runners.

Only certain injury risk factors could be explored as limited by the sample size in *Chapter 3*. Even though *Chapter 4* had a larger sample size, it was still limited to exploring factors collected in previous years and I could not explore certain trail running specific factors such as elevation gains, specific surface exposures, etc. Multivariate models were used to investigate the injury risk factors. However, injury is multifactorial in nature[36], and we could not account for all possible factors potentially contributing to injury in the analysis.

Regarding the developed TRISI, relevant factors to be included in the TRISI might have been missed by using a plain literature search performed by a single researcher. In hindsight, the original systematic review (*Chapter 2*) could have benefitted from including injury risk factors as variables of interest. I used a quantitative approach to collecting and analysing trail runners' perceptions of factors associated with injury. In this case, a qualitative research approach could

have given better insight into the complex phenomenon of injury in trail running. I tried establishing expert panels covering various fields of injury risk management and trail running experience in clinical injury management or participation. However, the TRISI is still based only on the input of 20 panellists. The TRISI cannot be used as a stand-alone instrument. It is a clinical decision aid, not taking the decision away from the clinician. The context in which the injury occurs matters,[43] therefore, keeping the clinician actively involved in the screening process could result in a better application of the findings in individualised injury risk management strategies. But I acknowledge that some experience in musculoskeletal injury assessment and rehabilitation is required by a clinician using the TRISI. For example, it will be of no worth if the TRISI indicates decreased muscle strength as an important contributor to injury risk. Still, the clinician has little experience/knowledge in designing specific conditioning/rehabilitative strategies. The feasibility of the TRISI has not yet been determined. Therefore, only a demonstration model of the application will be made available to clinicians involved in the implementation. A feasibility trial to determine user experience and usability of the tool is planned in postdoctoral research studies.

5. FUTURE RESEARCH DIRECTIONS

There is in trial running a lack of literature on the epidemiology of injury and associated injury risk factors, including prospectively collected training-related injury data. Authors should consider the following of a participant over longer periods to improve our understanding of real-world injury profiles and risk factors involved among trail runners.

Injury among shorter distance trail runners should be investigated. Clinical observations in the South African context are that this population are usually new to running/trail running or transitioning from other forms of running into trail running. We might see a unique injury profile and associated risk factors among shorter distance runners to be addressed in individualised injury risk management strategies.

To improve our knowledge of the injured tissue and pathology types in trail running, we need to consider using data from clinical assessments. We acknowledge that these studies will require more resources concerning medical staff and have financial implications on the remuneration of the additional research team members.

The epidemiology and associated injury risk factors among specific women and transgender populations should be investigated. These populations might present unique risk factors based on hormonal contributions/fluctuations.

Future studies need to consider reporting more accurately on trail running training exposure. Furthermore, the effect of a rapid increase in training load (running distance, running pace, frequency of running, elevation gain, etc.) should be investigated instead of weekly averages. Runners accustomed to high training volumes over the years might not be exposed to injury due to the gradual exposure to training demands over time.

Future studies should evaluate the feasibility of the TRISI to determine the usability and user experience before making the TRISI available to clinicians.

6. CLINICAL RECOMMENDATION

While working as musculoskeletal physiotherapist in the South African National Defence Force, I obtained clinical experience in injury management of soldiers who sustained injuries while running on off-road surfaces. Later, while working in high performance units across South Africa, I got exposed injury management of trail runners on elite and recreational levels, across all ages and genders, participating in trail running of various distances in various environments. Currently, more than 80% of my clinical work is consulting with injured trail runners. Even though all the recommendations provided in this section are in context of the findings from this thesis, I still acknowledge my potential confirmation bias when providing clinical recommendations in a field where research evidence is still limited.

6.1. Recommendations regarding the epidemiology of injury in trail running

The incidence and prevalence of injury in trail running have large variations among different studies.[1 10] From a clinical perspective, we might expect a higher incidence of injury when trail runners participate in regions with technical running terrains potentially resulting in acute joint instability episodes, ultra-events where runners will be exposed to more extreme fatigue and repetitive overuse, or in shorter distance trail runs where often inexperienced trail runners participate in. However, it would be inappropriate considering the findings of this thesis to make specific recommendations for clinicians or runners regarding expected injury incidences related to race vs training participation, influence of running surface and distance etc.

In terms of clinical characteristics of injury in trail running, the lower limb is the most injured anatomical region in trail runners.[1 10] But it is important to note that injuries are not isolated to the lower limb in trail running.[10] Furthermore, it is common to see gradual onset injuries such as tendinopathies in trail running, but sudden onset injuries resulting from acute trauma also occur in trail running.[4] Therefore, it is recommended that race medical teams prepare accordingly, not only in terms of medical supplies but also in selection of medical team members with wilderness medicine experience. For example, injuries such as joint sprains, concussions, and fractures could result in a runner not being able run/walk any further. In these cases, race medical teams need experienced members to be able to find and evacuate injured runners as soon as possible. Considering the more severe sudden onset injuries such as fractures[10] and challenges of medical care in remote environments,[38] it is recommended that trail runners participating in training or racing in remote regions obtain basic first aid knowledge to assist themselves or fellow injured runners while awaiting medical support.

6.2. Recommendations regarding injury risk in trail running

With regards to injury risk management in trail running we have limited research and poor quality of evidence to guide clinical decision-making. In my original research papers (*Chapter 3* and *4*) associated injury risk factors are reported. While in the living systematic review (*Chapter 6*) a further total of 17 injury risk factors are reported. These studies mainly used study design with no or limited follow-up periods and the injury risk factors have not yet been associated with injury in multiple studies tested in various populations of trail running. For this reason the TRISI was developed. However, the TRISI will still undergo further investigation to determine the feasibility, usability, and user experience of the TRISI before being made available to clinicians. Even though the TRISI cannot be implemented in clinical practice at this stage, the experts involved in the development gave valuable insights into trail running injury risk management. The experts highlighted the multifactorial nature of trail running injury through identifying multiple factors contributing to an increased risk for injury. These factors covered 10 domains of injury risk namely training, running equipment, demographics, previous injury, behavioural, psychological, nutrition, chronic disease, physiological, and biomechanical factors. It is recommended that clinicians consider the multiple factors specific contributing to injury risk in trail running when assessing a trail runner, developing injury risk management strategies, making a return to running decision, or clearing a runner to participate in race or training in remote environments. The injury risk management strategy needs to be

designed in context of the trail runners risk profile and planned trail running exposure. I further recommend that screening be done on a regular basis to account for the temporality of injury risk factors[36] and update injury risk management strategies accordingly.

7. CONCLUSION

I have developed a TRISI that could be used as clinical decision aid in trail running injury risk management. Gaps in the literature were identified regarding the epidemiology and associated injury risk in trail running and conducted original research to address certain research gaps. Finally, I have initiated a living systematic review to update the TRISI and assist clinicians and runners with an up-to-date source of research evidence regarding injury risk in trail running. The feasibility and user experience of the TRISI should be determined in future studies.

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SUMMARY

Trail running is characterised by running on off-road surfaces, in natural environments, and often involves large elevation changes. Trail running participation is popular and can play a key role in contributing to physical and mental health and promote public health. However, trail running also presents with a high risk of injury.

The consequences of injury in trail running are of concern as medical support in remote regions are challenging. Injured runners not being able to move usually have limited gear to protect them from the elements while awaiting medical care. This highlights the importance of identifying trail runners at increased risk for injury before trail running participation in remote regions. However, it is also important to identify increased injury risk in trail runners not participating in remote regions in order to design individualised injury risk management strategies. By mitigating the injury risk we contribute to trail runners having access to the health benefits of trail running, uninterrupted by injury.

To design injury risk management strategies, one has to consider what is the epidemiology and clinical characteristics of injury in trail running, and which factors are associated with an increased risk for sustaining these injuries. In evidence-based practice (EBP), this research evidence should then be used in combination with the clinician's clinical experience and applied to the context of the trail runner's unique preferences. However, at the start of this research project, limited research evidence was available on the epidemiology and clinical characteristics of injury and associated injury risk factors in trail running.

This PhD contributed to the knowledge gap through original research addressing the some of the gaps in trail running injury literature and developing a trail running injury screening instrument (TRISI) to be used as a clinical decision aid in injury risk management.

Chapter 2: Epidemiology of injury and illness among trail runners: A systematic review

To determine the baseline of epidemiology and clinical characteristics of injury in trail running, a systematic review was conducted. For the purpose of this thesis, I focussed on the results related to injury in this systematic review. The findings highlighted wide injury incidence ranges with 1.6–61.2 injuries per 1000 h of running and 65.0–95.4 illnesses per 1000 h of running. The most injured anatomical reported was the lower limb, mostly affecting the foot, knee, and lower leg. The review further highlighted that acute (sudden onset) injury also occur. The review highlighted the need for collecting injury-related data prospectively, including

training exposure in trail running. Furthermore, the review highlighted the limited research evidence on injury in shorter distance trail running.

Chapter 3: Epidemiology, clinical characteristics, and risk factors for running-related injuries among South African trail runners

Chapter 3 focused on addressing gaps identified in *Chapter 2*. The epidemiology, clinical characteristics and associated injury risk factors were investigated prospectively and included trail running training exposure. The main findings were an overall injury rate of 19.6 running-related injuries (RRIs) per 1000 h and an RRI mean prevalence of 12.3%. The most injured anatomical site was the lower limb (82.9%), affecting the knee (29.8%), shin/lower leg (18.0%), and the foot/toes (13.7%). Independent risk factors for RRIs among trail runners were a history of previous RRI in the past 12 months (p=0.0032) and having a chronic disease (p=0.0188).

Chapter 4: Independent risk factors predicting gradual onset injury in 2824 trail running race entrants: Safer XVIII study

Chapter 4 also focused on addressing gaps identified in *Chapter 2*. The epidemiology, clinical characteristics and associated injury risk factors were investigated specifically in shorter distance trail runners (10km and 22km) through analysing an existing dataset. The main findings reported were a retrospective annual incidence for gradual onset running-related injuries (GORRIs) was 13%. The most injured anatomical region was the lower limb (94%) with soft tissue injuries accounting for most (83%) GORRIs. Iliotibial band syndrome (22%), achilles tendon injury (10%), and hamstring injury (9%) were the most common specific GORRIs reported. Longer race distance (p<0.0001), increasing chronic disease composite score (p=0.0012), and a history of allergies (p=0.0056) were independent risk factors predicting GORRIs.

Chapter 5: Development of a Trail Running Injury Screening Instrument: A multiple Methods Approach

In *Chapter 5,* the development of the TRISI is presented. A quantitative multiple methods approach was used. The study utilised five phases that identified injury risk factors, determined

the relevance of each identified risk factor in a trail running context, created content of the Likert scale points from 0 to 4, rescaled the Likert scale points to determine numerical values for the content of each Likert scale point, and determined a weighted score for each injury risk factor that contributes to the overall combined composite score. A total of 26 risk factors were deemed relevant in trail running. The highest weighted scores for each injury risk factor were 5.53 (buying running shoes based on a running analysis and not primarily based on a good shoe fit), followed by 5.41 (not adhering to a specific running-related, supervised training plan), and 5.11 (competitive training). The final TRISI includes risk categories of training, running equipment, demographics, previous injury, behavioural, psychological, nutrition, chronic disease, physiological, and biomechanical factors.

Chapter 6: Trail running injury risk factors: A living systematic review

Chapter 6 is living systematic review that will be updated every six months over a five-year period. The aim of this living review is to provide an up to date summary of the current research evidence regarding injury risk in trail running to guide future updates of the TRISI. A secondary aim of the review is to provide an up to date summary of the epidemiology and clinical characteristics of injury in trail running. Currently, intrinsic factors associated with injury are more running experience, level A runner, and higher total propensity to sports accident questionnaire (PAD-22) score. Specific factors associated with an increased risk of cramping are a previous history of cramping and post-race biomarkers of muscle damage. Younger age and low skin phototypes are associated with sunburn. Extrinsic factors that are associated with injury include neglecting warm-up, no specialised running plan, training on asphalt, double training sessions per day, and physical labour occupations. Cramping is associated with a slower race finishing time. Sunburn is associated with more than three hours of training per day, shade as the primary mode of sun protection, and being single. The injury incidence range is recorded at 0.8 to 61.2 injuries/1000h of running and prevalence range is reported at 1.3% to 90%. The most injured anatomical region is the lower limb (83.3%) with the most common injured body areas being foot/toe (55.6%), ankle (50.0%), and hip/groin (50.0%). The most common injured tissue types are superficial tissue/skin injuries (72.2%) followed by muscle/tendon injuries (44.4%), and ligament/joint capsule injuries (38.9%). The most common specific injuries reported are blisters (50.0%), joint sprains (44.4%), and tendinopathies (38.9%).

Conclusion

In this PhD I have firstly established the gap in literature regarding the epidemiology and clinical characteristics of injury in trail running through conducting a systematic review. This followed with two original research papers to address the some of the gaps identified and further contributed to determining factors associated with injury among trail runners. I developed a TRISI to be used in future as a clinical decision aid in injury risk management in trail running. Lastly, a living systematic review is conducted to provide up to date evidence to be used in updating the TRISI.

ACKNOWLEDGEMENTS

To the *authors* that were involved in the studies of this thesis. I value your input and work done in this process. Especially those involved in the living systematic review with updated searches performed every six months. I am sure you regret signing up.

To the *research participants* and *expert panellists* that participated in the studies presented in this thesis. You sacrificed your valuable time and contributed to the sport of trail running. But, you also contributed to my PhD project. Without your participation, this project would not have been possible. Thank you.

To my *colleagues* in the Department of Physiotherapy, University of Pretoria. You eased my workload in times where I had to prioritise work related to the completion of this thesis. Without your help, I would still be working on this thesis for years to come. Thank you for your support *Elzette, Muhle, Annelie, Rozelle, Joyce*, and *Rubine*.

Prof Christa. You were the only one prepared to listen to my plea for research towards future safer trail running participation. You invested your time and energy into my projects. Your passion for research is contagious and work ethic is like no other. Thank you for always (literally always) being available to help. You opened so many doors for me and contributed so much to the success in my short career. Thank you Prof.

Willem. Before I met you, I knew you only as a legendary researcher. But after spending time with you, I realised that is only the tip of the ice berg. You are brutally honest, but kind. You maintain a balance between work and life, but always put your family first. This is the Willem van Mechelen I now know, the man I want to be more like. Thank you for your guidance throughout my PhD journey and the valuable life lessons.

Evert. At the start of this PhD journey I was afraid to open my mouth in your presence as I didn't want my inexperience to be so obvious. But your advice has always been delivered with such clarity and respect. I have grown immensely under your guidance. I signed up for a PhD, but you gave me so much more in confidence and growing towards being an independent researcher. Thank you Evert.

Elzette. You trained me as an undergraduate. You guided me in becoming a lecturer. You supervised on my PhD project. Thank you for your positive influence in so many stages of my career. But, more importantly, thank you for your friendship. Your support throughout this PhD process was immense (you were even prepared to babysit little Thomas so that I can write). I appreciate you Elzette.

Pa en *Ma.* You taught me to take pride in my work. Whether it is washing dishes or writing an essay, one should be able to stand back and be proud of your work. I am standing back now, and I am proud of the work in this thesis Mom and Dad. Thank you for shaping me.

Klein Thomas. You don't care about academic manuscripts. Your deep interest is in the texture of a leaf, the smell of a naartjie, the taste of milk, and the sound of you mother's voice. Thank you for your daily reminder of what is really important in life.

Lastly to *Carmi*. Simply put, without you this thesis would not have existed. No words can comprehend the extent of your sacrifice during this PhD journey. Your endless love and support carried me through to this point. Thank you for reminding me that "jy benodig slegs een graad, dit is n ruggraat". Ek het jou so lief.

Ek slaan my oë op na die berge: waar sal my hulp vandaan kom? My hulp is van die Here wat hemel en aarde gemaak het.

ABOUT THE AUTHOR

I (Carel Thomas Viljoen) was born in Bellville, South Africa, on 24 February 1986 and grew up mainly in the northern regions of South Africa. In 2009, I completed my undergraduate Physiotherapy degree at the University of Pretoria and in 2016, completed a coursework masters in clinical sports Physiotherapy at the University of the Free State, Bloemfontein. My Physiotherapy career started in the South African National Defence Force where I worked as Physiotherapist stationed at the Tempe Base in the Free State province. In the military I first got exposed to off-road-running and working clinically with injuries sustained while running on off-road terrains. My career turned towards injury management in rugby and I worked in professional rugby for a few years. Currently, I lecture in the Department of Physiotherapy, responsible for undergraduate teaching in sports Physiotherapy and clinical training in sport and orthopaedic rehabilitation. My clinical work is based in the Sport, Exercise Medicine and Lifestyle Institute (SEMLI) which is an International Olympic Committee (IOC) research centre in Pretoria. Here I act as head of clinical Physiotherapy and coordinate postgraduate research in the Physiotherapy division. The majority of my clinical workload consists of injury management among trail runners. I love participating in trail running (full disclosure, I am a below average trail runner). It takes me far away from the daily rush, does wonders for my mental well-being and I get to see places of extreme natural beauty. But, I have first-hand experience in the challenges of medical support in trail running settings. If I want to promote trail running to others, then surely I need to contribute to the safety of the sport as well. This is where my research into trail running injuries started and brought about this PhD project. A privilege to combine my passion for research with the sport I love.

APPENDICES

APPENDIX 1: CHAPTER 2. Supplementary material (S1): Search strategy

MeSH or text words	**Medline Ovid** - MeSH - .tw. - Truncation - .mp.	**Results**	**PubMed** - MeSH - All fields - Truncation	**Results**	**Scopus** -Title, abstract, keyword -Language English -Document Type (Review & Article)	**Results**	**SportDiscus** - No specific search fields used	**Results**	**Cinahl** **Results**	**Health Source: Nursing/ Academic** - No specific search fields used	**Results**	**Health Source: Consumer ed.** - No specific search fields used **Results**	**Medline Ebsco** **Results**	**Results**	**Cochrane Trials)** -Tittle -Abstract -Keywords	**Results**
Set 1	1 fell run& (tw)	4	epidemiol*	2023842	"trail run*"	23	"trail run*"	1889	79	trail run*	42	354	trail run*	133	(trail run*) **and**	72
Set 2	trail run$ (tw)	57	illness*	511070	"fell run*"	19	"fell run*"	112	15	fell run*	4	14	fell run*	54	Injur*	13
Set3	off-road run$ (tw)	7	injur*	1153884	"off-road run*"	18	"off-road run*"	89	11	off road racing	4	9	off-road run*	52		
Set 4	sky run$ (tw)	0	injuries[MeSH Terms]	867693	"sky run*"	4	"sky run*"	32	3	off-road run*	3	23	sky run*	6		
Set 5	mountain run$ (tw)	20	physiol*	4551223	"mountain run*"	128	"mountain run*"	868	41	sky run*	1	3	mountain run*	139		
Set 6	vertical kilometer$ (tw)	3	health	4428665	"vertical kilometer"	14	"vertical kilometer*"	6	2	mountain run*	28	87	vertical kilometre*	20		
Set 7	ultra run$ (tw)	29	health[MeSH Terms]	341227	"ultra run*"	80	"ultra run*"	748	106	vertical kilometre*	2	1	ultra run*	285		
Set 8	ultrarunning.mp	5	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7	10730725	"ultrarun*"	45	"ultrarun*"	5 871	15	ultra run*	23	59	ultrarun*	23		
Set 9	ultrarun$.tw.	15	ultramarathon*	419	"ultramarathon*"	547	"ultra marathon*"	454	103	ultrarun*	13	66	ultra marathon*	234		
Set 10	ultramarathon.tw.	239	ultra marathon*	212	"ultra marathon"	303	"ultramarathon*"	4432	202	S8 or S9	26	89	ultramarathon*	419		
Set 11	ultramarathon.mp.	242	ultrarun*	23	1-10 OR AND	1122	**OR 1-10**	9 094	459	ultra marathon*	22	47	(MH "Health+")	340 218		
Set 12	ultra marathon.tw.	106	ultra run*	51	"health*"	4875 230	(MH "Health+")	124	297 262	ultramarathon*	34	81	health	4 073 560		
Set 13	ultra marathon.mp.	109	vertical kilometer	32	"physiol*"	2699 769	"health"	284 737	1 449 971	S11 or S12	46	92	S10 OR S11	4 088 765		

Set 14	used **or** for sets 1-13	442	mountain run*	29	"injur*"	1501 479	**S12 OR S13**	284 737	1 478 797	(S11 OR S12) AND (S1 OR S2 OR S4 OR S5 OR S6 OR S7 OR S10 OR S13)	46	92	MH "Physiology+"	129 124		
Set 15	exp Health/ =	224 096	mountain running	269	"illness*"	5742 53	(MH "Physiology+") "Physiology"	123 676 ----------	15 453 302 190	health*	98 1 92 6	226 728	Physiology	3 750 587		
Set 16	exp Physiology/	46 917	(sky run*) OR sky running	44	"epidemiology*"	5210 99	**S15 OR S16**	123 676	313 160	physiol*	17 8 37 7	22 089	S14 OR S15	3,789,260		
Set 17	exp "wounds and injuries"	460 938	(sky run) OR sky running	39	OR	8996 003	(MH "Wounds and Injuries+"	33	250 177	injur*	80 64 8	10 531	MH "Wounds and Injuries+"	866 296		
Set 18	illness$.tw.	146 104	((off-road running) OR off-road run) OR off road run	189	AND ar OR rev	588	"injur*"	141 389	262 068	illness*	93 99 8	11 436	injur*	1 148 448		
Set 19	exp Epidemiology /	15 411	(fell running) OR fell run*	716	AND English	565	"illness"	12 906	167 362	epidemiology*	76 99 9	4 677	illness	476,912		
Set 20	OR for set 15-19	871 807	trail run*[Text Word] OR trail run[Text Word]	159			(MH "Epidemiology+")	13	586 879	S15 OR S16 OR S17 OR S18 OR S19	1 178 32 7	248 430	MH "Epidemiology+"	25 753		
Set 21	sets 20 and 14	53	trail run	106			"Epidemiol*"	30 248	395 105	S14 AND S20	26	10	Epidemiol*	1 965 716		
Set 22	limit to English & French	53	9-21 OR	1945			OR 14, 17, 18, 19, 20, 21, 22	493 941	2 486 538				S13 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21	9 802 767		
Set 23	limit to Humans	53	S8 AND S22	1338			**11 AND 23 English or French**	954	271				S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10	1 077		
Set 24			Limiters: Humans, English, French	978									S22 AND S23	788		

Set 25													Limiters: English French	762		
TOTAL DOC		**53**		**978**	**280 (previous total of scopus)**	**588**		**954**	**271**		**26**	**10**		**762**		**13**

APPENDIX 2: CHAPTER 2. Supplementary material (S2): Modified Downs and Black checklist for assessing quality of studies

Trail running injury and illness studies (n=16)					
	Article	Graham et al. (2012)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0		
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*		0		
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?			0	11 males gave consent to participate in the study. However, the for part of a population of

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				runner participating in the 2009 Gobi Desert Challenge. No mention was made of this population size and demographics in order to determine if this was a representative sample.
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			BRUMS – measuring mood stated which is not applicable to our review.
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**8/15**				

Trail running injury and illness studies (n=16)					
	Article	Krabak et al. (2011)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1		Decimals reported (Table 2 and 3)	
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*	1			396 of the total of 407 runners participated in the study

Internal validity		Yes=1	No=0	Unable to determine =0	Comment if needed
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.		0		
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.		0		
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes*.	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**10/15**				

Trail running injury and illness studies (n=16)					
	Article	Scheer & Murray (2011)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0	Eligibility criteria	
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0		
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0	Only descriptive statistics used for the specific aim of this study	
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	

12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.	1			All participants of the 2010 Al Andalus Ultra Trail race were included
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			Descriptive statistics
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**8/15**				

Trail running injury and illness studies (n=16)					
	Article	McGowan et al. (2015)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below*).	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.		N/A	Cross-sectionally recorded medical encounters during single stage evenets	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0		
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*	1			

Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.		0		
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**9/15**				

Trail running injury and illness studies (n=16)				
	Article	Vernillo et al. (2015)		
Reporting		**Yes=1**	**No=0**	**Comment if needed**
1	Is the hypothesis/aim/objective of the study clearly described?	1		

2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		N/A	Cross-sectionally recorded injury following a race	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.		0		
17	In trials and cohort studies, do the analyses adjust for different lengths of	1			

	follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.				
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**9/15**				

Trail running injury and illness studies (n=16)				
	Article	Costa et al. (2016)		
Reporting		**Yes=1**	**No=0**	**Comment if needed**
1	Is the hypothesis/aim/objective of the study clearly described?	1		
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1		
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1		

6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0		
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the			0	

	answer should be yes. Studies where differences in follow-up are ignored should be answered no.				
18	Were the statistical tests used to assess the main outcomes appropriate? The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27				0	
TOTAL SCORE	**8/15**				

Trail running injury and illness studies (n=16)				
	Article	Hespanhol Junior et al. (2017)		
Reporting		**Yes=1**	**No=0**	**Comment if needed**
1	Is the hypothesis/aim/objective of the study clearly described?	1		
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1		
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1		
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates	1		

	used were appropriate and the question should be answered yes.				
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1		Included decimals (refer to table 4)	
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)?	1			

	For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.				
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**10/15**				

Trail running injury and illness studies (n=16)				
	Article	Malliaropoulos et al. (2015)		
Reporting		**Yes=1**	**No=0**	**Comment if needed**
1	Is the hypothesis/aim/objective of the study clearly described?	1		
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1		
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1		
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes	1		
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0	N/A, cross-sectionally recorded injuries.
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1		

External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	

Power		Yes=1	No=0	Unable to determine =0	Comment if needed
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**8/15**				

Trail running injury and illness studies (n=16)					
	Article	Hoffman & Stuempfle (2015)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0		
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample*			0	

	of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.				
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*	1			
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**9/15**				

Trail running injury and illness studies (n=16)					
	Article	González-Lázaro et al. (2020)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*		0		
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0		
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0	Not applicable, pure descriptive study	
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*		0		
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	

Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**5/15**				

Trail running injury and illness studies (n=16)					
	Article	Matos et al. (2020)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0	Cross sectional study	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*	1			
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**

16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**9/15**				

Trail running injury and illness studies (n=16)				
	Article	Banfi et al. (1996)		
Reporting		**Yes=1**	**No=0**	**Comment if needed**
1	Is the hypothesis/aim/objective of the study clearly described?	1		
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1		
3	Are the characteristics of the patients included in the study clearly described?		0	

	In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given				
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.		0		
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0		
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*		0		
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.		0		
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different		0		

	lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.				
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes*.	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes*.	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**6/15**				

Trail running injury and illness studies (n=16)				
	Article	Stuempfle et al. (2016)		
Reporting		**Yes=1**	**No=0**	**Comment if needed**
1	Is the hypothesis/aim/objective of the study clearly described?	1		
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1		
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1		
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed	1		

	data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.				
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0		
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*	1			
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data*	1			

	(normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.				
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*			0	
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**8/15**				

Trail running injury and illness studies (n=16)				
	Article	Stuempfle & Hoffman (2015)		
Reporting		**Yes=1**	**No=0**	**Comment if needed**
1	Is the hypothesis/aim/objective of the study clearly described?	1		
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1		
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0	
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1		
7		1		
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0	Plain descriptive study

External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*	1			
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	

Power		Yes=1	No=0	Unable to determine =0	Comment if needed
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**8/15**				

Trail running injury and illness studies (n=16)					
	Article	Stuempfle et al. (2013)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0		
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?			0	

	The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.				
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than			0	

	5%? Sample sizes have been calculated to detect a difference of x% and y%.				
TOTAL SCORE	**7/15**				

Trail running injury and illness studies (n=16)					
	Article	Baska et al. (1990)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*		0		
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0		
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	

12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.			0	
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.			0	
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*			0	
26	Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.			0	
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**5/15**				

APPENDIX 3: CHAPTER 3. Supplementary file 1

Start of Block: Consent

Q1
The aim of this study is to collect data that will help guide future injury/illness prevention strategies among trail runners.

Your participation is truly appreciated among the trail running community.

I have read the participant information (participant info). I understand that I may withdraw from this study at any time without further question.
I hereby consent to participate in this study.

○ I agree (1)

End of Block: Consent

Start of Block: Demographic data

Q7 **Initials and Surname**

_____
_____
_____
_____
_____

Q9 **Email address** (where we can send your questionnaire every second week)

_____
_____
_____
_____
_____

*

Q27 **ID number** (to identify your data on the follow-up questionnaires)

_____

Q14 **Age**

_____

Q16 **Sex**

○ Male (1)

○ Female (2)

Q18 **What is your current height (cm)?**

_____

Q20 **What is your current weight (kg)?**

_____

Q21 **Are you planning to participate in a trail run of 21 km or more, during the next 6 months?**

- Yes (1)
- No (2)

Q22 **On what surfaces do you train/run?**

	Often (1)	Sometimes (2)	Rarely (3)
Dirt roads (trails) (1)			
Street (tarred/paved surfaces) (2)			
Grass (3)			
Athletic track (tartan) (4)			
Treadmill (5)			

Q24 **For what time period have you been actively participating in RUNNING as a sport?**

▼ Select time (1) ... 10 years or more (12)

Q28 **For what time period have you been actively participating in TRAIL RUNNING as a sport?**

▼ Select time (1) ... 10 years or more (12)

Q26 **Did you receive any advice regarding trail running shoes before?**

- ○ Yes (1)
- ○ No (2)

Q30 If yes, what advice did you receive?

- ☐ Anti-pronation (1)
- ☐ Anti-supination (2)
- ☐ Neutral shoe (3)
- ☐ Ankle support (4)
- ☐ Orthotics (5)
- ☐ Raised heel (6)
- ☐ Front-foot support (7)
- ☐ For increased weight (8)

Q29 What brand shoe do you use most often during trail running?

▼ Adidas (1) ... Other (20)

Q29 **Did you sustain any running related injuries in the PAST TWELVE MONTHS?**

- ○ Yes (1)
- ○ No (2)

Q30 **If yes, do you still at this stage experience similar symptoms from this injury?**

- ○ Yes (1)
- ○ No (2)

Q31 **Please specify the DIAGNOSIS of this injury (or location of symptoms if diagnosis was not made)**

- ☐ Diagnosis (1) _____
- ☐ Location of injury (2) _____

Q32 **Are you suffering from any CHRONIC DISEASES i.e. hypertension, asthma, diabetes, cholesterol?**

- ○ Yes (1)
- ○ No (2)

Q33 **If yes, please list your chronic diseases.**

_____

Q32 **Please list all other MEDICATIONS and/or SUPPLEMENTS that you currently use.**

_____

End of Block: Demographic data

APPENDIX 4: CHAPTER 3. Supplementary file 2

Survey flow

Block: OSTRC (1 Question)
Block: Training data (10 Questions)
Block: Injury/Illness Effect (5 Questions)

Branch: New Branch
If
If Was an INJURY responsible for your difficulty in running participation over the PAST TWO WEEKS? No Is Selected

Block: Illness ? (1 Question)

Branch: New Branch
If
If Was an ILLNESS responsible for your difficulty in running participation over the PAST TWO WEEKS? Yes Is Selected

Block: Illness 1 (9 Questions)

Branch: New Branch
If
If Do you have any OTHER ILLNESS to record? Yes Is Selected

Block: Illness 2 (9 Questions)

Branch: New Branch
If
If Do you have any OTHER ILLNESS to record? Yes Is Selected

Block: Illness 3 (8 Questions)

EndSurvey:

EndSurvey:

EndSurvey:

EndSurvey:

Block: Injury 1 (8 Questions)

Branch: New Branch
If
If Do you have any OTHER INJURY to record? Yes Is Selected

Block: Injury 2 (8 Questions)

Branch: New Branch
If
If Do you have any OTHER INJURY to record? Yes Is Selected

Block: Injury 3 (7 Questions)

Block: Illness ? (1 Question)

Branch: New Branch
If
If Was an ILLNESS responsible for your difficulty in running participation over the PAST TWO WEEKS? Yes Is Selected

Block: Illness 1 (9 Questions)

Branch: New Branch
If
If Do you have any OTHER ILLNESS to record? Yes Is Selected

Block: Illness 2 (9 Questions)

Branch: New Branch
If
If Do you have any OTHER ILLNESS to record? Yes Is Selected

Block: Illness 3 (8 Questions)

EndSurvey:

EndSurvey:

EndSurvey:

EndSurvey:

Page Break

Start of Block: OSTRC

Q1 Please answer all questions regardless of whether or not you have experienced health problems in the **PAST TWO WEEKS**.
If you have several illness or injury problems, please refer to the one that has been your worst problem in the **PAST TWO WEEKS**. You will have a chance to register other problems at the end of the questionnaireTop of Form **Let's start!**

End of Block: OSTRC

Start of Block: Training data

Q63 Initials & Surname

_____

Q68 ID number

_____

Q57 How many **running** sessions did you do in the PAST TWO WEEKS?

▼ 0 (1) ... more than 14 (16)

Q58 How many of these running sessions were **ran on trails** in the PAST TWO WEEKS?

▼ 0 (1) ... more than 14 (16)

Q59 What **distance (km)** did you run over the PAST TWO WEEKS?

_____

Q82 What was the **total ascent (m)** you got during your runs over the PAST TWO WEEKS?

_____

Q68 What was the total descent (m) you got during your runs over the PAST TWO WEEKS?

_____

Q70 At what **average altitude (m)** did you train during the PAST TWO WEEKS?

_____

Q65 What was your **average running pace (min/km)** over the PAST TWO WEEKS?

▼ 3:30 (1) ... Did not run (29)

Q60 What **cross training** did you do and **for how many hours** in the PAST TWO WEEKS?
Cycling : _____ (1)
Strength training : _____ (2)
Rowing : _____ (3)
Swimming : _____ (4)
Pilates : _____ (5)
Functional training : _____ (6)
Other sports (squash, tennis, soccer etc.) : _____ (7)
None : _____ (8)
Total : _____

End of Block: Training data

Start of Block: Injury/Illness Effect

Q2 To what extent have you **MODIFIED YOUR TRAINING OR COMPETITION** due to injury, illness or other health problems during the PAST TWO WEEKS?

- ○ No modification (1)
- ○ To a minor extent (2)
- ○ To a moderate extent (3)
- ○ To a major extend (4)
- ○ Could not participate at all (5)

Skip To: End of Survey If To what extent have you MODIFIED YOUR TRAINING OR COMPETITION due to injury, illness or other hea... = No modification

Q3 To what extent has injury, illness or other health problems affected your **PERFORMANCE** during the PAST TWO WEEKS?

- ○ No effect (1)
- ○ To a minor extent (2)
- ○ To a moderate extent (3)
- ○ To a major extend (4)
- ○ Could not participate at all (5)

Q4 To what extent have you **experienced symptoms/health complaints** during the PAST TWO WEEKS?

- ○ No symptoms/health complaints (1)
- ○ To a minor extent (2)
- ○ To a moderate extent (3)
- ○ To a major extend (4)
- ○ Could not participate at all (5)

Q5 To what extent have you experienced **PAIN** related to your sport during the PAST TWO WEEKS?

- ○ No pain (1)
- ○ Mild pain (2)
- ○ Moderate pain (3)
- ○ Severe pain (4)
- ○ Could not participate at all (5)

Q6 Was an **INJURY** responsible for your difficulty in running participation over the PAST TWO WEEKS?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Block If Was an INJURY responsible for your difficulty in running participation over the PAST TWO WEEKS? = No

End of Block: Injury/Illness Effect

Start of Block: Illness ?

Q29 Was an **ILLNESS** responsible for your difficulty in running participation over the PAST TWO WEEKS?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Was an ILLNESS responsible for your difficulty in running participation over the PAST TWO WEEKS? = No

End of Block: Illness ?

Start of Block: Illness 1

Q67 **Is this the first time you have registered this illness through this monitoring system?**

- ○ Yes (1)
- ○ No, I have reported the same problem in the previous 4 weeks (2)
- ○ No, I have reported the same problem previously, but it was more than 4 weeks ago (3)

Q30 **Please check the boxes corresponding to the major symptoms you have experienced during the PAST TWO WEEKS. You may select several alternatives.**

- ☐ Fever (1)
- ☐ Fatigue/malaise (2)
- ☐ Swollen glands (3)
- ☐ Sore throat (4)
- ☐ Blocked nose/running nose/sneezing (5)
- ☐ Cough (6)
- ☐ Breathing difficulty/tightness (7)
- ☐ Nausea (8)
- ☐ Vomiting (9)
- ☐ Diarrhoea (10)
- ☐ Constipation (11)
- ☐ Abdominal pain (12)
- ☐ Irregular pulse/arrhythmia (13)
- ☐ Chest pain/Angina (14)
- ☐ Other pain (15)
- ☐ Headache (16)
- ☐ Fainting (17)

- ☐ Numbness/pins and needles (18)
- ☐ Sunburn (19)
- ☐ Rash with itchiness (20)
- ☐ Ear symptoms (21)
- ☐ Eye symptoms (22)
- ☐ Symptoms from urinary tract/genitalia (23)
- ☐ Anxiety (24)
- ☐ Depression/sadness (25)
- ☐ Irritability (26)
- ☐ Muscle Cramps – Generalised (unspecific region of the body) (27)
- ☐ Muscle Cramps – Localised (in specific location) (28)
- ☐ Other (please specify) (29) _____

Q31 **Please indicate the body system involved with your illness.**

- Brain and Nervous system (1)
- Heart and Blood vessels (2)
- Lungs and Respiratory tract (3)
- Digestive system (4)
- Kidney and bladder (5)
- Muscle (i.e. muscle cramps, muscle weakness) (6)
- Bone (i.e. osteopenia, osteoporosis, low bone density) (7)
- Immune (i.e. infections) (8)
- Metabolic or Endocrine (i.e. glands, hormones) (9)
- Skin (10)
- Do not know (11)

Q35 **Do have a specific diagnosis for your illness? Please specify**

- Yes (please specify) (1) _____
- No (2)

Q36 **Who made the diagnosis of your illness?**

- Doctor (1)
- Physiotherapist (2)
- Other health care professional (3)
- Coach (4)
- Self-diagnosed (5)

Q37 **Did your illness have a GRADUAL or SUDDEN onset?**

- ○ Gradual (1)
- ○ Sudden (2)

Q38 **How was your illness treated or managed?**

- ☐ Self-medicated (1)
- ☐ Antibiotics (2)
- ☐ Referral to other health care professional (3)
- ☐ Other drug therapies (4)

Q40 **Please state the NUMBER OF DAYS that you had to completely miss training/races due to this illness.**

_____

Q41 **Do you have any OTHER ILLNESS to record?**

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Do you have any OTHER ILLNESS to record? = No

End of Block: Illness 1

Start of Block: Illness 2

Q68 **Is this the first time you have registered this illness through this monitoring system?**

- ○ Yes (1)
- ○ No, I have reported the same problem in the previous 4 weeks (2)
- ○ No, I have reported the same problem previously, but it was more than 4 weeks ago (3)

Q40 **Please check the boxes corresponding to the major symptoms you have experienced during the PAST TWO WEEKS. You may select several alternatives.**

- ☐ Fever (1)
- ☐ Fatigue/malaise (2)
- ☐ Swollen glands (3)
- ☐ Sore throat (4)
- ☐ Blocked nose/running nose/sneezing (5)
- ☐ Cough (6)
- ☐ Breathing difficulty/tightness (7)
- ☐ Nausea (8)
- ☐ Vomiting (9)
- ☐ Diarrhoea (10)
- ☐ Constipation (11)
- ☐ Abdominal pain (12)
- ☐ Irregular pulse/arrhythmia (13)
- ☐ Chest pain/Angina (14)
- ☐ Other pain (15)
- ☐ Headache (16)
- ☐ Fainting (17)

- [ ] Numbness/pins and needles (18)
- [ ] Sunburn (19)
- [ ] Rash with itchiness (20)
- [ ] Ear symptoms (21)
- [ ] Eye symptoms (22)
- [ ] Symptoms from urinary tract/genitalia (23)
- [ ] Anxiety (24)
- [ ] Depression/sadness (25)
- [ ] Irritability (26)
- [ ] Muscle Cramps – Generalised (unspecific region of the body) (27)
- [ ] Muscle Cramps – Localised (in specific location) (28)
- [ ] Other (please specify) (29) _____

Q41 **Please indicate the body system involved with your illness.**

- Brain and Nervous system (1)
- Heart and Blood vessels (2)
- Lungs and Respiratory tract (3)
- Digestive system (4)
- Kidney and bladder (5)
- Muscle (i.e. muscle cramps, muscle weakness) (6)
- Bone (i.e. osteopenia, osteoporosis, low bone density) (7)
- Immune (i.e. infections) (8)
- Metabolic or Endocrine (i.e. glands, hormones) (9)
- Skin (10)
- Do not know (11)

Q42 **Do have a specific diagnosis for your illness? Please specify**

- Yes (please specify) (1) _____
- No (2)

Q43 **Who made the diagnosis of your illness?**

- Doctor (1)
- Physiotherapist (2)
- Other health care professional (3)
- Coach (4)
- Self-diagnosed (5)

Q44 **Did your illness have a GRADUAL or SUDDEN onset?**

- ○ Gradual (1)
- ○ Sudden (2)

Q45 **How was your illness treated or managed?**

- ☐ Self-medicated (1)
- ☐ Antibiotics (2)
- ☐ Referral to other health care professional (3)
- ☐ Other drug therapies (4)

Q46 **Please state the NUMBER OF DAYS that you had to completely miss training/races due to this illness.**

_____

Q47 **Do you have any OTHER ILLNESS to record?**

- ○ Yes (1)
- ○ No (2)

End of Block: Illness 2

Start of Block: Illness 3

Q69 **Is this the first time you have registered this illness through this monitoring system?**

- ○ Yes (1)
- ○ No, I have reported the same problem in the previous 4 weeks (2)
- ○ No, I have reported the same problem previously, but it was more than 4 weeks ago (3)

Q48 **Please check the boxes corresponding to the major symptoms you have experienced during the PAST TWO WEEKS. You may select several alternatives.**

- ☐ Fever (1)
- ☐ Fatigue/malaise (2)
- ☐ Swollen glands (3)
- ☐ Sore throat (4)
- ☐ Blocked nose/running nose/sneezing (5)
- ☐ Cough (6)
- ☐ Breathing difficulty/tightness (7)
- ☐ Nausea (8)
- ☐ Vomiting (9)
- ☐ Diarrhoea (10)
- ☐ Constipation (11)
- ☐ Abdominal pain (12)
- ☐ Irregular pulse/arrhythmia (13)
- ☐ Chest pain/Angina (14)
- ☐ Other pain (15)
- ☐ Headache (16)
- ☐ Fainting (17)

- [ ] Numbness/pins and needles (18)
- [ ] Sunburn (19)
- [ ] Rash with itchiness (20)
- [ ] Ear symptoms (21)
- [ ] Eye symptoms (22)
- [ ] Symptoms from urinary tract/genitalia (23)
- [ ] Anxiety (24)
- [ ] Depression/sadness (25)
- [ ] Irritability (26)
- [ ] Muscle Cramps – Generalised (unspecific region of the body) (27)
- [ ] Muscle Cramps – Localised (in specific location) (28)
- [ ] Other (please specify) (29) _____

Q49 **Please indicate the body system involved with your illness.**

- Brain and Nervous system (1)
- Heart and Blood vessels (2)
- Lungs and Respiratory tract (3)
- Digestive system (4)
- Kidney and bladder (5)
- Muscle (i.e. muscle cramps, muscle weakness) (6)
- Bone (i.e. osteopenia, osteoporosis, low bone density) (7)
- Immune (i.e. infections) (8)
- Metabolic or Endocrine (i.e. glands, hormones) (9)
- Skin (10)
- Do not know (11)

Q50 **Do have a specific diagnosis for your illness? Please specify**

- Yes (please specify) (1) _____
- No (2)

Q51 **Who made the diagnosis of your illness?**

- Doctor (1)
- Physiotherapist (2)
- Other health care professional (3)
- Coach (4)
- Self-diagnosed (5)

Q52 **Did your illness have a GRADUAL or SUDDEN onset?**

- ○ Gradual (1)
- ○ Sudden (2)

Q53 **How was your illness treated or managed?**

- ☐ Self-medicated (1)
- ☐ Antibiotics (2)
- ☐ Referral to other health care professional (3)
- ☐ Other drug therapies (4)

Q54 **Please state the NUMBER OF DAYS that you had to completely miss training/races due to this illness.**

_____

End of Block: Illness 3

Start of Block: Injury 1

Q64 Is this the **first time** you have **registered this injury** through this monitoring system?

- ○ Yes (1)
- ○ No, I have reported the same problem in the previous 4 weeks (2)
- ○ No, I have reported the same problem previously, but it was more than 4 weeks ago (3)

Q7 Please select the box that best describes the **LOCATION** of your injury. If the injury involves several locations please select the main area.
If you have **multiple injuries** please complete a **separate registration** of each one.

- ○ Head/face (1)
- ○ Neck (2)
- ○ Shoulder (including clavicle) (3)
- ○ Upper arm (4)
- ○ Elbow (5)
- ○ Forearm (6)
- ○ Wrist (7)
- ○ Hand/fingers (8)
- ○ Chest/ribs (9)
- ○ Abdomen (10)
- ○ Thoracic spine (11)
- ○ Lumbar spine (12)
- ○ Pelvis/buttock (13)
- ○ Hip/groin (14)
- ○ Thigh (front - quadricep) (15)
- ○ Thigh (back - hamstring) (16)
- ○ Knee (17)
- ○ Lower leg (18)
- ○ Ankle (19)
- ○ Foot/toes (20)

Q8 Please select a box that best describes your **TYPE OF INJURY.**

- ○ Concussion (symptoms like disorientation, dizziness, loss of memory, nausea or vomiting due to a blow to the head) (1)
- ○ Fracture (traumatic - broken bone caused by sudden impact) (2)
- ○ Stress fracture (overuse - fracture in a weight bearing bone caused by repetitive stress (e.g. running), a stress fracture in one of the small bones in the foot will typically cause severe pain at the beginning of a run, moderate pain during the run and severe pain at the end and after the run) (3)
- ○ Other bone injuries (4)
- ○ Dislocation, subluxation (the total or partial displacement or misalignment of bones in a joint, most often caused by a sudden impact to the joint) (5)
- ○ Tendon rupture (tearing of a tendon that occurs when the forces placed upon the tendon exceed its tensile strength) (6)
- ○ Tendinosis/tendinopathy (all non-inflammatory and inflammatory conditions affecting a tendon, "tendinitis") (7)
- ○ Ligamentous rupture (tearing of the bands of fibrous tissue connecting bones or cartilages, serving to support and strengthen joints) (8)
- ○ Sprain (wrenching or twisting of a joint, with partial rupture of its ligaments, accompanied by severe pain, impaired function, swelling, heat and discolouration of the skin) (9)
- ○ Lesion of meniscus or cartilage (injuries of meniscus [knee] or joint surfaces) (10)
- ○ Muscle strain (11)
- ○ Muscle rupture/tear (12)
- ○ Contusion/haematoma/bruise (13)
- ○ Arthritis/synovitis/bursitis (inflammation of any part of a joint or structures near the joint, characterize by pain on movement, tenderness, heat and swelling) (14)
- ○ Fasciitis/aponeurosis injury (inflammation or injury of a sheet like tendinous expansion, e.g. plantar fasciitis) (15)
- ○ Impingement (compression of a nerve, blood vessel, tendon, ligament or muscle through a constricted space, e.g. sciatica) (16)
- ○ Skin laceration/cut/lesion (17)
- ○ Skin abrasion/chafing (18)

- ○ Dental injury/broken tooth (19)
- ○ Nerve injury/spinal cord injury (20)
- ○ Muscle cramps or spasm (21)
- ○ I don't know (22)
- ○ Other (please specify) (23) _____

Q9 **Who** made the **diagnosis** of your injury?

- ○ Doctor (1)
- ○ Physiotherapist (2)
- ○ Other health care professional (3)
- ○ Coach (4)
- ○ Self-diagnosed (5)

Q10 Did your injury have a **GRADUAL** or **SUDDEN** onset?

- ○ Gradual (1)
- ○ Sudden (2)

Q11 Was the **injury due to a specific action?** (fall, jump, landing, increased pace, overstretch, collision etc.)

- ○ Yes (please specify the action) (1) _____
- ○ No (2)

Q14 Please state the **NUMBER OF DAYS** that you had to completely **miss training/races** due to this injury.

_____

Q15 Do you have any **OTHER INJURY** to record?

- Yes (1)
- No (2)

End of Block: Injury 1

Start of Block: Injury 2

Q83 Is this the **first time** you have **registered this injury** through this monitoring system?

- Yes (1)
- No, I have reported the same problem in the previous 4 weeks (2)
- No, I have reported the same problem previously, but it was more than 4 weeks ago (3)

Q84 Please select the box that best describes the **LOCATION** of your injury. If the injury involves several locations please select the main area.
If you have **multiple injuries** please complete a **separate registration** of each one.

- ○ Head/face (1)
- ○ Neck (2)
- ○ Shoulder (including clavicle) (3)
- ○ Upper arm (4)
- ○ Elbow (5)
- ○ Forearm (6)
- ○ Wrist (7)
- ○ Hand/fingers (8)
- ○ Chest/ribs (9)
- ○ Abdomen (10)
- ○ Thoracic spine (11)
- ○ Lumbar spine (12)
- ○ Pelvis/buttock (13)
- ○ Hip/groin (14)
- ○ Thigh (front - quadricep) (15)
- ○ Thigh (back - hamstring) (16)
- ○ Knee (17)
- ○ Lower leg (18)
- ○ Ankle (19)
- ○ Foot/toes (20)

Q85 Please select a box that best describes your **TYPE OF INJURY.**

- ○ Concussion (symptoms like disorientation, dizziness, loss of memory, nausea or vomiting due to a blow to the head) (1)
- ○ Fracture (traumatic - broken bone caused by sudden impact) (2)
- ○ Stress fracture (overuse - fracture in a weight bearing bone caused by repetitive stress (e.g. running), a stress fracture in one of the small bones in the foot will typically cause severe pain at the beginning of a run, moderate pain during the run and severe pain at the end and after the run) (3)
- ○ Other bone injuries (4)
- ○ Dislocation, subluxation (the total or partial displacement or misalignment of bones in a joint, most often caused by a sudden impact to the joint) (5)
- ○ Tendon rupture (tearing of a tendon that occurs when the forces placed upon the tendon exceed its tensile strength) (6)
- ○ Tendinosis/tendinopathy (all non-inflammatory and inflammatory conditions affecting a tendon, "tendinitis") (7)
- ○ Ligamentous rupture (tearing of the bands of fibrous tissue connecting bones or cartilages, serving to support and strengthen joints) (8)
- ○ Sprain (wrenching or twisting of a joint, with partial rupture of its ligaments, accompanied by severe pain, impaired function, swelling, heat and discolouration of the skin) (9)
- ○ Lesion of meniscus or cartilage (injuries of meniscus [knee] or joint surfaces) (10)
- ○ Muscle strain (11)
- ○ Muscle rupture/tear (12)
- ○ Contusion/haematoma/bruise (13)
- ○ Arthritis/synovitis/bursitis (inflammation of any part of a joint or structures near the joint, characterize by pain on movement, tenderness, heat and swelling) (14)
- ○ Fasciitis/aponeurosis injury (inflammation or injury of a sheet like tendinous expansion, e.g. plantar fasciitis) (15)
- ○ Impingement (compression of a nerve, blood vessel, tendon, ligament or muscle through a constricted space, e.g. sciatica) (16)
- ○ Skin laceration/cut/lesion (17)
- ○ Skin abrasion/chafing (18)

- ○ Dental injury/broken tooth (19)
- ○ Nerve injury/spinal cord injury (20)
- ○ Muscle cramps or spasm (21)
- ○ I don't know (22)
- ○ Other (please specify) (23) _____

Q86 **Who** made the **diagnosis** of your injury?

- ○ Doctor (1)
- ○ Physiotherapist (2)
- ○ Other health care professional (3)
- ○ Coach (4)
- ○ Self-diagnosed (5)

Q87 Did your injury have a **GRADUAL** or **SUDDEN** onset?

- ○ Gradual (1)
- ○ Sudden (2)

Q88 Was the **injury due to a specific action?** (fall, jump, landing, increased pace, overstretch, collision etc.)

- ○ Yes (please specify the action) (1) _____
- ○ No (2)

Q89 Please state the **NUMBER OF DAYS** that you had to completely **miss training/races** due to this injury.

_____

Q90 Do you have any **OTHER INJURY** to record?

- Yes (1)
- No (2)

End of Block: Injury 2

Start of Block: Injury 3

Q99 Is this the **first time** you have **registered this injury** through this monitoring system?

- Yes (1)
- No, I have reported the same problem in the previous 4 weeks (2)
- No, I have reported the same problem previously, but it was more than 4 weeks ago (3)

Q100 Please select the box that best describes the **LOCATION** of your injury. If the injury involves several locations please select the main area.
If you have **multiple injuries** please complete a **separate registration** of each one.

- ○ Head/face (1)
- ○ Neck (2)
- ○ Shoulder (including clavicle) (3)
- ○ Upper arm (4)
- ○ Elbow (5)
- ○ Forearm (6)
- ○ Wrist (7)
- ○ Hand/fingers (8)
- ○ Chest/ribs (9)
- ○ Abdomen (10)
- ○ Thoracic spine (11)
- ○ Lumbar spine (12)
- ○ Pelvis/buttock (13)
- ○ Hip/groin (14)
- ○ Thigh (front - quadricep) (15)
- ○ Thigh (back - hamstring) (16)
- ○ Knee (17)
- ○ Lower leg (18)
- ○ Ankle (19)
- ○ Foot/toes (20)

Q101 Please select a box that best describes your **TYPE OF INJURY.**

- ○ Concussion (symptoms like disorientation, dizziness, loss of memory, nausea or vomiting due to a blow to the head) (1)
- ○ Fracture (traumatic - broken bone caused by sudden impact) (2)
- ○ Stress fracture (overuse - fracture in a weight bearing bone caused by repetitive stress (e.g. running), a stress fracture in one of the small bones in the foot will typically cause severe pain at the beginning of a run, moderate pain during the run and severe pain at the end and after the run) (3)
- ○ Other bone injuries (4)
- ○ Dislocation, subluxation (the total or partial displacement or misalignment of bones in a joint, most often caused by a sudden impact to the joint) (5)
- ○ Tendon rupture (tearing of a tendon that occurs when the forces placed upon the tendon exceed its tensile strength) (6)
- ○ Tendinosis/tendinopathy (all non-inflammatory and inflammatory conditions affecting a tendon, "tendinitis") (7)
- ○ Ligamentous rupture (tearing of the bands of fibrous tissue connecting bones or cartilages, serving to support and strengthen joints) (8)
- ○ Sprain (wrenching or twisting of a joint, with partial rupture of its ligaments, accompanied by severe pain, impaired function, swelling, heat and discolouration of the skin) (9)
- ○ Lesion of meniscus or cartilage (injuries of meniscus [knee] or joint surfaces) (10)
- ○ Muscle strain (11)
- ○ Muscle rupture/tear (12)
- ○ Contusion/haematoma/bruise (13)
- ○ Arthritis/synovitis/bursitis (inflammation of any part of a joint or structures near the joint, characterize by pain on movement, tenderness, heat and swelling) (14)
- ○ Fasciitis/aponeurosis injury (inflammation or injury of a sheet like tendinous expansion, e.g. plantar fasciitis) (15)
- ○ Impingement (compression of a nerve, blood vessel, tendon, ligament or muscle through a constricted space, e.g. sciatica) (16)
- ○ Skin laceration/cut/lesion (17)
- ○ Skin abrasion/chafing (18)

- ○ Dental injury/broken tooth (19)
- ○ Nerve injury/spinal cord injury (20)
- ○ Muscle cramps or spasm (21)
- ○ I don't know (22)
- ○ Other (please specify) (23) _____

Q102 **Who** made the **diagnosis** of your injury?

- ○ Doctor (1)
- ○ Physiotherapist (2)
- ○ Other health care professional (3)
- ○ Coach (4)
- ○ Self-diagnosed (5)

Q103 Did your injury have a **GRADUAL** or **SUDDEN** onset?

- ○ Gradual (1)
- ○ Sudden (2)

Q104 Was the **injury due to a specific action?** (fall, jump, landing, increased pace, overstretch, collision etc.)

- ○ Yes (please specify the action) (1) _____
- ○ No (2)

Q105 Please state the **NUMBER OF DAYS** that you had to completely **miss training/races** due to this injury.

_____

End of Block: Injury 3

APPENDIX 5: CHAPTER 3. Supplementary file 3

Table 1: The frequency of tissue and pathology types of RRIs among trail runners (% of RRIs) (*n*=205)

Tissue	Pathology type	*n*	% of all injuries (*n*=205)
Muscle/Tendon	**All**	**108**	**52.7**
	Muscle injury	42	20.5
	Muscle cramps	6	2.9
	Tendinopathy	57	27.8
	Tendon rupture	3	1.5
Nervous	**All**	**2**	**1.0**
	Peripheral nerve injury	2	1.0
Bone	**All**	**10**	**4.9**
	Bone stress injury	6	2.9
	Bone contusion	1	0.5
	Other bone injuries	3	1.5
Cartilage/Synovium/Bursa	**All**	**16**	**7.8**
	Cartilage injury	5	2.4
	Synovitis/Capsulitis/Bursitis	11	5.4
Ligament/Joint capsule	**All**	**18**	**8.8**
	Joint sprain (ligament tear or acute instability episode)	18	8.8
Superficial tissues/skin	**All**	**10**	**4.9**
	Contusion (superficial)	5	2.4
	Laceration	3	1.5
	Abrasion	1	0.5
	Blisters	1	0.5
Other		**20**	**9.8**
Missing		**21**	**10.2**

APPENDIX 6: CHAPTER 6. Supplementary appendix 1: Search strategy

	Ovid MEDLINE	Results	PubMed	Results	Scopus	Results	SPORTDiscus	Results	CINAHL	Results	Health Source Nursing/Academic	Results	Cochrane Library	Results	MEDLINE EBSCO	Results
Set 1	trail run*	97	"trail run*"	146	"trail run*"	265	"trail run*"	1462	"trail run*"	86	"trail run*"	27	"trail run*"	5	"trail run*"	146
2	trailrun*	1	"trailrun*"	14	"trailrun*"	2	"trailrun*"	5	"trailrun*"	1	"trailrun*"	0	"trailrun*"	0	"trailrun*"	1
3	fell run*	6	"fell run*"	467	"fell run*"	19	"fell run*"	74	"fell run*"	5	"fell run*"	2	"fell run*"	2	"fell run*"	6
4	fellrun*	0	"fellrun*"	0	"fellrun*"	0	"fellrun*"	2	"fellrun*"	0	"fellrun*"	0	"fellrun*"	0	"fellrun*"	0
5	off road run*	0	"off road run*"	9	"off road run*"	19	"off road run*"	37	"off road run*"	5	"off road run*"	1	"off road run*"	0	"off road run*"	11
6	off-road run*	9	"off-road run*"	9	"off-road run*"	19	"off-road run*"	37	"off-road run*"	5	"off-road run*"	1	"off-road run*"	0	"off-road run*"	11
7	sky run*	0	"sky run*"	2	"sky run*"	4	"sky run*"	3	"sky run*"	1	"sky run*"	3	"sky run*"	0	"sky run*"	26
8	skyrun*	4	"skyrun*"	5	"skyrun*"	12	"skyrun*"	29	"skyrun*"	2	"skyrun*"	2	"skyrun*"	0	"skyrun*"	5
9	mountain run*	28	"mountain run*"	36	"mountain run*"	136	"mountain run*"	397	"mountain run*"	21	"mountain run*"	7	"mountain run*"	2	"mountain run*"	40
10	ultra run*	35	"ultra run*"	58	"ultra run*"	80	"ultra run*"	329	"ultra run*"	25	"ultra run*"	16	"ultra run*"	2	"ultra run*"	58
11	ultrarun*	21	"ultrarun*"	67	"ultrarun*"	45	"ultrarun*"	6500	"ultrarun*"	16	"ultrarun*"	15	"ultrarun*"	0	"ultrarun*"	27
12	mountain marathon*	21	"mountain marathon*"	23	"mountain marathon*"	37	"mountain marathon*"	57	"mountain marathon*"	13	"mountain marathon*"	5	"mountain marathon*"	3	mountain marathon**	24
13	ultra marathon*	182	"ultra marathon*"	252	"ultra marathon*"	311	"ultra marathon*"	432	"ultra marathon*"	123	"ultra marathon*"	25	"ultra marathon*"	7	"ultra marathon*"	250
14	ultramarathon*	394	"ultramarathon*"	713	"ultramarathon*"	565	"ultramarathon*"	4532	"ultramarathon*"	2206	"ultramarathon*"	46	"ultramarathon*"	51	"ultramarathon*"	500
15	ultratrail	7	"ultratrail"	36	"ultratrail"	19	"ultratrail"	13	"ultratrail"	8	"ultratrail"	0	"ultratrail"	4	"ultratrail"	10
16	ultra trail	19	"ultra trail"	34	"ultra trail"	68	"ultra trail"	127	"ultra trail"	13	"ultra trail"	1	"ultra trail"	2	"ultra trail"	32
Set 1 combined with **OR** operator		710		1409		1337		9192		2353		152		22		2426
Set 2	injur*	1127578	"injur*"	1266044	"injur*"	1735597	"injur*"	159211	"injur*"	326758	"injur*"	100707	"injur*"	442	"injur*"	1261887
18	epidemiolog*	1935817	"epidemiolog*"	2244761	"epidemiolog*"	855904	"epidemiolog*"	36122	"epidemiolog*"	490419	"epidemiolog*"	117924	"epidemiolog*"	14	"epidemiolog*"	2234540
19	risk factor*	1088206	"risk factor*"	1187062	"risk factor*"	1520669	"risk factor*"	34572	"risk factor*"	488666	"risk factor*"	120287	"risk factor*"	31066	"risk factor*"	1183709
20	health*	3452886	"health*"	5992350	"health*"	6030459	"health*"	389753	"health*"	2045297	"health*"	1233743	"health*"	300509	"health*"	5584375
21	medical encounter*	1041	"medical encounter*"	1230	"medical encounter*"	1515	"medical encounter*"	55	"medical encounter*"	649	"medical encounter*"	291	"medical encounter*"	36	"medical encounter*"	1226
Set 2 combined with **OR** operator		6139727		8531791		8871484		526402		2802787		1361744		321185		8176935
Set 1 and Set 2 combined with **AND** operator		252		701		386		736		764		62		7		672
Limiters applied as stipulated in the eligibility criteria. Not all databases have the option to apply all the stipulated limiters.		252		517		310		353		635		32		3		653
		none		Language Humans		Article type Language		Article type Language		Article type Language		Article type Language		Article type		
														FINAL RESLUTS	DUPLICATES REMOVED	
														2755	1613	

APPENDIX 7: CHAPTER 6. Supplementary appendix 2: Standardised data extraction form

Table 1: Methods and demographics

Authors and publication year	Study design	Data collection procedure (how did they collect data? Self-reported questionnaire, medical encounters etc.)	Setting (Country, race or training, race name, race distance, environmental conditions etc.)	Number of participants (n)	Age (mean, intervals etc – depending on how the authors reported the data)	Sex Frequency (n, % - as authors reported the data)	BMI (exactly as authors reported the data)
Babi et al. (2018)							
Buckler & Higgins (2000)							
Costa et al. (2016)							
Dawadi et al. (2020)							
Garcia-Malinis et al. (2020)							
Gonzales-Lazaro et al. (2021)							
Graham et al. (2012)							
Graham et al. (2021)							
Hespanhol Junior et al. (2017)							
Hoffman & Stuempfle (2015)							
Krabak et al. (2011)							
Malliaropoulos et al. (2015)							
Matos et al. (2020) A							
Matos et al. (2020) B							
McGowan & Hoffman (2015)							
Scheer & Murray (2011)							
Scheer et al. (2014)							
Vernillo et al. (2016)							
Viljoen et al. (2021)							

Table 2: Epidemiology of injury

Authors and publication year	Injury definition	Follow-up period and intervals	Frequency (n, %) of injury characteristics as stated by 2020 IOC consensus statement				Injury severity (exactly as study reported the data) days lost, OSTRC severity score etc.	Incidence of injury (per 1000 hours, per 1000 runners)	Injury prevalence
			Injury: Anatomical region	Injury: Body area	Injury: Tissue type	Injury: Pathology type			
Babi et al. (2018)									
Buckler & Higgins (2000)									
Costa et al. (2016)									
Dawadi et al. (2020)									
Garcia-Malinis et al. (2020)									
Gonzales-Lazaro et al. (2021)									
Graham et al. (2012)									
Graham et al. (2021)									
Hespanhol Junior et al. (2017)									
Hoffman & Stuempfle (2015)									
Krabak et al. (2011)									
Malliaropoulos et al. (2015)									
Matos et al. (2020) A									
Matos et al. (2020) B									
McGowan & Hoffman (2015)									
Scheer & Murray (2011)									
Scheer et al. (2014)									
Vernillo et al. (2016)									
Viljoen et al. (2021)									

Table 3: Associated injury risk factors

Authors and publication year	Statistical analysis used to describe the association with injury risk. Provide detail on the exact statistical tests used where possible.	Risk factors & association (For example: Running distance, OR 95% CI)	Protective factor & association (For example: Running distance OR 95% CI)
Babi et al. (2018)			
Buckler & Higgins (2000)			
Costa et al. (2016)			
Dawadi et al. (2020)			
Garcia-Malinis et al. (2020)			
Gonzales-Lazaro et al. (2021)			
Graham et al. (2012)			
Graham et al. (2021)			
Hespanhol Junior et al. (2017)			
Hoffman & Stuempfle (2015)			
Krabak et al. (2011)			
Malliaropoulos et al. (2015)			
Matos et al. (2020) A			
Matos et al. (2020) B			
McGowan & Hoffman (2015)			
Scheer & Murray (2011)			
Scheer et al. (2014)			
Vernillo et al. (2016)			
Viljoen et al. (2021)			

APPENDIX 8: CHAPTER 6. Supplementary appendix 3

Modified Downs and Black quality assessment tool

	Report	Babi et al. (2018)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?		0		
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		N/A	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0		
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the*		0		

	proportion of the source population from which the patients are derived, the question should be answered as unable to determine.				
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			N/A
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*			0	Assumption of normality
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**8/15**				

	Report	**Buckler & Higgins (2000)**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?		0		
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*		0		
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*		0		
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*		0		
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		N/A – Did not finish the race	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*			0	
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?			0	

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*			0	Aim – methods - results
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			N/A
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*			0	
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**5/15**				

	Report	**Costa et al. (2016)**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0	Both significant and non-significant	
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*		0		
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?			0	

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**11/15**				

	Report	Dawadi et al. (2020)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1		N/A for descriptive/nominal data	
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		N/A	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0		
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*	1			
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?	1			

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			N/A
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			N/A
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**12/15**				

	Report	**Garcia-Malinis et al. (2020)**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0	Participants from race – do not describe eligibility criteria	
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		N/A** Check how the N/A will be considered (i.e., lower total score, or as "1")	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*		0		Not clear if they invited all participants from race.
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?		0		

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			N/A*
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*		0		
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**10/15**				

	Report	Gonzales-Lazaro et al. (2021)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*		0	Third reviewer: WvM. Unclear description of de nominator. The injury rate is expressed per 1000h of running and per 1000 participants. However, they report in the text about 28 injured participants. Unclear if these participants have sustained multiple injuries, or not. So unclear what exactly is meant by the MSK injury rate of 1.6 injuries/1000h and 5.9 injuries/1000 runners	
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		N/A	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1		N/A – No statistics	
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the*	1			

	proportion of the source population from which the patients are derived, the question should be answered as unable to determine.				
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	6167/4831. No validation
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*			0	Third reviewer. WvM: no sign of data dredging. Unclear to me if I should now answer with a 1 or a 0. However, the results presented are based on the a priori set purpose of the study.
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*		0		
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*			0	Third reviewer: WvM. The paper is very unclear about this. They state that the design is retrospective. Yet, it is totally unclear at what time point the Q's were send to the participants? Immediately after the race? Etc.? Given the retrospective design assessing loss to FU is not applicable. At best one could assess non-response to the Q. THEREFORE, UNABLE TO DETERMINE

Power		Yes=1	No=0	Unable to determine =0	Comment if needed
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**9/15**				

Report		Graham et al. (2012)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*		0	Brief mention – not clear the different domains. BRUMS scale not even referenced.	
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		N/A	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0		
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?			0	Doesn't say that all were recruited

	The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.				
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	Not reported %, nor validation of sample.
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			N/A
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*			0	
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			No losses
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than			0	NR

	5%? Sample sizes have been calculated to detect a difference of x% and y%.				
TOTAL SCORE	**8/15**				

Report		**Graham et al. (2021)**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0		
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		No losses	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*		0		Convenience sample

12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	Not reported
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			Assumed ok (non-parametric used) – small sample size
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			Reported in methods
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			No losses
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	NR
TOTAL SCORE	**11/15**				

	Report	Hespanhol et al. (2017)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		2.2%	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1		N/A - descriptive	
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*		0		convenience
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?			0	

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*		0		Statistical analysis performed and not described
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*		0		At least 6 months, but corrected by differences.
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*			0	Not reported
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			2.2%
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.		0		Please refer to page 373 in the Discussion. "…the sample size calculation suggested a cohort of 152 participants."
TOTAL SCORE	**9/15**				

	Report	Hoffman & Stuempfle (2015)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1		All from the race	
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*	1			All from the race
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?			0	No information about those that did not respond

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**13/15**				

	Article	**Krabak et al. (2011)**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0	No p-values reported	
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*	1			All participants from race were invited
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?			0	% reported but no validation of sample was conducted

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**12/15**				

	Report	**Malliaropoulos et al. (2015)**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1		Questionnaire	
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1		Criteria of active participation in trail races	
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		No losses	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*		0		
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?		0		

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*		0		
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*		0		"For the categorical variables that have more than two categories one-way ANOVA was performed". Maybe I'm interpreting this wrong (after seeing the results reported in tables). Third reviewer: WvM. In my opinion the tests were appropriate. However, there was no correction for multiple testing. So I would still rate this with a 0. Also: the paper is very confusing: when exactly were the data collected? What is their definition of prevalence? Was there a priori sufficient power to do all these tests?
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than			0	

	5%? Sample sizes have been calculated to detect a difference of x% and y%.				
TOTAL SCORE	**10/15**				

Report		**Matos et al. (2020) A**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*		0	Third reviewer.WvM: in the introduction it is stated: 'Therefore, the aim of this research is to characterize trail running injuries in a cohort of male and female Portuguese recreational trail running athletes.' However; from this statement it is unclear what the **main outcome** of the study is. Also, the methods section does not provide a statement on a **main outcome.**	
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0	Characteristics of the sample reported but no inclusion/exclusion criteria.	
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		No losses	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an*			0	No description of how they were selected or recruited

	unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.				
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	Authors report that the sample is representative (% estimated) but no validation…
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*			0	Third reviewer. WvM. As the main outcome has not been defined this construct can only be rated '0'. Nevertheless the method to calculate the rate/1000 h. seems appropriate, but a calculation of the 95% CI is lacking. So, '0' it should be.
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			N/A
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**

27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	Authors state sample size is sufficient but no power analysis was conducted
TOTAL SCORE	**9/15**				

	Report	**Matos et al. (2020) B**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		Assumed no losses	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an*			0	No mention of recruitment strategy

	unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.				
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	Not reported
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	No power analysis

TOTAL SCORE	12/15

	Report	McGowan & Hoffman (2015)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*		0	Not clear how the encounter form was developed or what variables included.	
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0	Third reviewer. Not clear in the methods… see end of second paragraph. WvM. I agree to rate this with '0', as there is no description in the text. The tables are, however, such that some information can be derived on subjects chracteristics, but insufficient. So, '0'.	
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an*			0	

	unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.				
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	Not clear if all participants from race agreed to participate
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*			0	No mention of normality
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*			0	
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	No power analysis

TOTAL SCORE	8/15

	Report	Scheer & Murray (2011)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*		0	No, but probably because of the study design	
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*		0	ditto	
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1		N/A	
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1		N/A	
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the*	1			All runners from race invited

	proportion of the source population from which the patients are derived, the question should be answered as unable to determine.				
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*			0	
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			N/A
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			N/A
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*			0	
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	No inferential statistics…
TOTAL SCORE	**10/15**				

	Report	**Scheer et al. (2014)**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0		
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*	1			All runners from race
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?			0	% identified but not validated

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**12/15**				

	Report	Vernillo et al. (2016)			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?		0		
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*	1			All runners invited
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?			0	% that responded but no validation information

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*			0	
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	1			medical records.
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	
TOTAL SCORE	**11/15**				

	Report	**Viljoen et al. (2021)**			
Reporting		**Yes=1**	**No=0**	**Comment if needed**	
1	Is the hypothesis/aim/objective of the study clearly described?	1			
2	Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no*	1			
3	Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given*	1			
6	Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	1			
7	Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the interquartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
9	Have the characteristics of patients lost to follow-up been described? *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.*	1			
10	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	1			
External validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
11	Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*	1			
12	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?			0	Stated by authors that not possible

	The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.				
Internal validity		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
16	If any of the results of the study were based on "data dredging", was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	1			
17	In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	1			
18	Were the statistical tests used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example nonparametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.*	1			
20	Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*			0	Self-reported
26	Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	1			
Power		**Yes=1**	**No=0**	**Unable to determine =0**	**Comment if needed**
27	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.			0	No power
TOTAL SCORE	**12/15**				

APPENDIX 9: CHAPTER 6. Supplementary appendix 4

Table 3: Trail running injury incidence, prevalence, clinical characteristics, and severity

Author(s) and publication year	Injury definition	Follow-up period and intervals	Incidence of injury	Injury prevalence	Frequency (n, %) of injury characteristics as stated by 2020 IOC consensus statement				Injury severity
					Anatomical region	Body area	Tissue type	Pathology type	
Studies that included only race-related injury outcomes (n=13)									
Buckler & Higgins (2000)[1]	Medical encounters on race day	Only followed-up for the duration of the race	Not reported	Not reported	Lower limb Head and neck Upper limb	Ankle Foot Hand Hip/groin Head	Tendon Nail Skin Ligament / joint capsule Cartilage / synovium / bursa	Blisters: n=7 (10%) Achilles tendonitis: n=3 (4.2%) In growing toenail: n=1 (1.4%) Dislocated metacarpophalangeal joint of the thumb: n=1 (1.4%) Trochanteric bursitis: n=1 (1.4%) Semimembranosus bursitis: n=1 (1.4%) Talocalcaneal ligament sprain: n=1 (1.4%) Dog bite: n=1 (1.4%) Laceration on head: n=1 (1.4%)	Not reported
Costa et al. (2016)[2]	Dermatological injury diagnosed visually	Event 1: MSUM [a] Prospectively followed up over 4 days Event 2: Continuous marathon 24 h Prospectively followed-up for the duration of the race	Not reported	Event 1: MSUM [a] 89% Event 2: Continuous marathon (24 h) 14%	Lower limb	Foot	Skin	Blisters Subungual haematoma Chafing/abrasion Sunburn	Not reported

Dawadi et al. (2020)[3]	Medical encounters	Prospectively followed up over 7 days	MSK: [b] 1.2 injuries/1000km run 170 injuries/1000 runners	MSK: [b] 17%	Lower limb	Ankle	Skin Ligament / joint capsule	MSK [b] (sprain/strain): n=17 (ankle sprain most commonly reported) Abrasion/laceration: n=12 Blisters: n=8 Sunburn: n=1	Not reported
Garcia-Malinis et al. (2020)[4]	Self-reported sunburn	None	Not reported	45.1%	Not reported	Not reported	Skin	Sunburn	Not reported
Gonzales-Lazaro et al. (2021)[5]	Self-reported injury: Major injury: could not further participate in the race Minor injury: continue with race participation	Not reported	5.9 injuries/1000 runners 1.6 injuries/1000h of running	Not reported	Lower limb: 78% Upper limb: 18% Trunk: 7%	Ankle: 32% Knee: 14% Foot/toe: 11%	Not reported	Not reported	Major injury: 25% Minor injury: 75%
Graham et al. (2012)[6]	Injuries clinically diagnosed following an assessment	Data recorded twice per day over 7 days	Not reported	Not reported	Lower limb	Lower leg Distal stump (above knee amputee) Achilles region Foot	Skin	% of injured participants: Abrasion: 100% (n=11) Blisters: 100% (n=11)	Not reported
Graham et al. (2021)[7]	Medical encounters	Prospectively followed up over 3 days	Not reported	83.3%	Trunk Lower limb	Back Knee Ankle Lower leg Hip/groin	Skin	Abrasions: n=7 (58.3%) Blisters: n=2 (16.6%) Frost injury: n=2 (16.6%) Hip and back pain: no frequencies provided	Not reported
Hoffman & Stuempfle (2015)[8]	Self-reported muscle cramping during an event	Data recorded once-off 1–15 days post-race	Not reported	Full muscle cramping: 14.3%	Lower limb Trunk Upper limb	Lower leg Thigh Hip/groin Forearm Upper arm Hand	Muscle	Muscle cramping of: Calf: 57.5%, Quadriceps: 57.5%, Hamstring: 45.0%, Hip flexors: 17.5%, Trunk: 10.0%, Hip adductors: 2.5%, Ankle dorsiflexors: 7.5% , Forearm: 7.5%, Foot: 5.0%, Upper arm: 2.5%, Hand: 2.5%	Not reported

Krabak et al. (2011)[9]	Medical encounter: Disability sustained during a race, resulting in a medical encounter	7-day period (during each of the four events)	Injury rates/1000 runners (95% CI) MSK [b] (major): 46.2 (25.2-77.5) MSK [b] (minor): 670.0 (581.0-768.7) Skin (major): 39.6 (20.4-69.2) Skin (minor): 2726.1 (2543.3-2918.5) Injury rates/1000h of running (95% CI) MSK [b] (major): 0.8 (0.4-1.3) MSK [b] (minor): 11.2 (9.8-12.9) Skin (major): 0.7 (0.3-1.1) Skin (minor): 45.8 (42.8-48.9)	Not reported	Lower extremity (92.6%), Hip & lumbar spine injuries (3.8%), Upper limb, thoracic spine & head/neck regions (3.6%)	Hip/groin Lumbosacral Thoracic spine	Skin Bursa Tendon	Bursitis: n =12 Sprain: n=27 Strain: n=28 Tendonitis: n=122 Abrasion: n=43 Blister: n=652 Cellulitis: n=9 Hematoma: n=107 Other: n=55	Major: unable to continue in race (n=26) Minor: able to continue in race (n=1029)
McGowan & Hoffman (2015)[10]	Medical encounters	During the race and immediate post-race	Not reported	Not reported	Not reported	Not reported	Muscle Ligament / joint capsule Nervous	Sprain, strain or tendinitis: n=7 (0.9%), Muscle cramping: n=6 (0.8%), Muscular pain: n=5 (0.7%), Contusion: n=2 (0.3%), Concussion: n=1 (0.1%), Skin wound: n=1 (0.1%), Visual impairment: n=1 (0.1%)	Not reported
Scheer & Murray (2011)[11]	Medical encounters	5 days: Data recorded daily during a stage race	Overall Incidence (injury and illness): 56.5%	Not reported	Lower limb	Ankle Lower leg Hip / groin	Skin Cartilage / synovium / bursa	The number of consultations: Blisters: n=33, patellofemoral pain: n=9, chafing: n=9, Ankle inversion injury: n=5, trochanteric bursitis: n=3, muscle cramps: n=3,	Runners not able to complete the race: n=9

								achilles tendinopathy: n=2, dog bite: n=2, subungual hematoma: n=2, ultramarathoner's ankle: n=1, quadriceps muscle pain: n=1, tibialis anterior muscle pain: n=1, laceration: n=1	
Scheer et al. (2014)[12]	Blisters as inspected by the researcher	5 days: Data recorded daily during a stage race	Not reported	76%	Lower limb	Toe: n=71 (65%), Ball of the foot: n=18 (16%), Heel: n=15 (14%), Sole: n=6 (5%)	Skin	Blisters: n=110	Not reported
Vernillo et al. (2016)[13]	Medical encounters reported during the race	None	Total injuries and illnesses: n=132 Injury rates/1000 runners (90% CI): MSK: [b] 614.3 (559.0-761.7) Skin: 314.3 (286.0-389.7) Injury rates/1000h (90% CI): MSK: [b] 61.2 (48.0–78.1) Skin: 31.3 (22.2–44.2)	Not reported	Lower limb Head and neck	Neck Foot Ankle Thigh Knee	Muscle Tendon Ligament / joint capsule Skin	Cramps: n=16 (26.2%), plantar fasciitis: n=16 (28.6%), ankle sprain: n=16 (28.6%), knee sprain: n=8 (14.3%), thigh strain: n=8 (14.3%), foot blisters: n=7 (53.8%), achilles tendinopathy: n=4 (7.1%), neck/cervical spine strain: n=4 (7.1%), laceration: n=2 (15.4%), subungual hematoma: n=2 (15.4%), chafing: n=2 (15.4%)	Not reported
Studies that included training/race-related injury outcomes (n=6)									
Babi´ et al. (2018)[14]	None	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported
Hespanhol Junior et al. (2017)[15]	Disorders of the MSK [b] system or concussions	Median: 34.0 weeks (IQR [c] 28.0–36.0)	Overall: 10.7 RRIs [d] injuries rate/1000h of running	Overall: 22.4 % (95 % CI [e] 20.9-24.0). Males: 23.0 % (21.3-	Lower limb Trunk Upper limb Multiple regions	Lower leg: n=49 (20.6%), knee: n=44 (18.9%), foot: n=36 (14.9%), achilles: n=31 (12.8%), pelvis/hip/	Muscle: n=67 (27.7%), tendon: n=57 (23.6%), ligament: n=18 (7.4%), bone: n=13 (5.4%), fascia:	Achilles tendon injury: n=31 (12.8%), Calf muscle trigger points/ spasm: n=26 (10.7%), Knee pain undiagnosed: n=21 (8.7%),	Average OSTRC [f] severity score: 35.0 (22.0-55.7)

	Acute onset: linked to a specific injury event. Overuse injuries: not linked to a identifiable event. Recurrent RRI: [d] same location and of the same type as the index RRI,[d] Re-injuries: after full recovery Exacerbations: not fully recovered		(95%: CI [e] 9.4-12.1) Males: 11.3 (9.7-12.9) Females: 9.1 (6.6-11.6) Overuse: 8.1 (6.9-9.3) Acute: 2.7 (2.0-3.4)	24.7) Females: 20.7 % (18.2-23.2), Overuse: 17.7 % (15.9-19.5) Acute: 4.1 % (3.3-5.0) Not reported Total number of injuries: n=242		groin: n=25 (10.3%), upper leg: n=23 (9.5%), ankle: n=22 (9.1%), lower back: n=5 (2.1%), chest: n=2 (0.8%), wrist/hand: n=2 (0.8%), multiple regions: n=3 (1.2%)	n=9 (3.7%), skin: n=8 (3.3%), cartilage: n=7 (2.9%), joint (multiple tissues) n=2 (0.8%), nerve: n=2 (0.8%), bursa: n=1 (0.4%), unknown: n=58 (24.0%)	Ankle sprains: n=17 (7.0%), Buttock muscle strain: n=10 (4.1%), Foot pain undiagnosed: n=10 (4.1%), Muscle strain lower limb (crossing anatomical boundaries): n=9 (3.7%), Hamstring strain: n=8 (3.3%), Plantar fasciitis strain: n=8 (3.3%), ITB [g] syndrome: n=7 (2.9%), Tenoperiostitis of lower leg: n=7 (2.9%), Blisters foot: n=5 (2.1%), Knee tendon injury: n=5 (2.1%), Lower leg pain undiagnosed: n=5 (2.1%), Hip/groin pain undiagnosed: n=4 (1.7%), Patellar tendinopathy: n=3 (1.2%), Lumbar pain undiagnosed: n=3 (1.2%), Patellofemoral pain: n=3 (1.2%), Thigh muscle strain/ spasm/trigger points: n=3 (1.2%)	Time loss: The average duration of RRIs [d] 2.0 weeks
Malliaropoulos et al. (2015)[16]	Self-reported injury	None	Not reported	90% of runners reported at least on injury Total injuries (n=135)	Lower limb Trunk	% of injured runners Low back: 42,5%, Knee: 40.0%, Hip: 35.0%, Thigh (lateral): 35.0%, Foot plantar: 32.5%, Thigh (posterior): 30.0%, Leg (anterior): 27.5%, Foot dorsal: 27.5%, Leg (posterior): 22.5%, Thigh (medial): 20.0%, Achilles tendon: 20.0%, Thigh (anterior): 5.0%	Muscle Tendon Bone Cartilage / synovium / bursa	% of all diagnosed injuries Overuse bone stress injuries: 22% ITB: 16% Spinal disc injuries: 14% Meniscus injuries: 14% Hamstring strain: 12% Achilles tendonitis: 7% Plantar fasciitis: 7% Morton's Neuroma: 5% Tibiofibular joint injury: 2% Adductor tendonitis: 2%	Grade 1: n=68 (50.4%) symptoms that appear after running. Grade 2: n=2 (1.5%) appears hours after running. Grade 3: n=14 (10.4%) appears

									during running. Grade 4: n=51 (37.8%) chronic symptoms Time loss: None: n=73 (54%) 1-5 days: n=30 (22.22%) <3 weeks: n=16 (11.85%) > 3 weeks: n=16 (11.85%)
Matos et al. (2020) A[17]	Not given	12 months retrospectively	All: 10 injuries/1000h Males: 10.13 Females: 9.62	87.8% of participants injured	Lower limb Trunk Head and neck	Knee: n=377 (17.5%), Ankle: n=312 (14.5%), Leg: n=192 (8.9%), Toes: n=173 (8%), Anterior thigh: n=108 (5%), Posterior thigh: n=103 (4.8%), Lumbar spine: n=98 (4.5%), Hip: n=97 (4.5%), Other: n=85 (3.9%), Cervical spine: n=30 (1.4%), Dorsal spine: n=25 (1.2%), Chest: n=11 (0.5%), Ears: n=9 (0.4%)	Toenails: n=535 (24.8%) Skin Muscle Tendon Bone Ligament / joint capsule	Blisters: n=554 (20%) Irritation (chafing): n=387 (14%), Superficial wound: n=321 (12%), Sprains: n=318 (11%), Micro strain: n=126 (5%) Shin splints: n=122 (4%) ITB syndrome: n=181 (7%), Plantar fasciitis: n=108 (4%), Tendinitis (other areas): n=108 (4%) Achilles tendinitis: n=94 (3%), Contusion: n=92 (3%), Patellofemoral pain: n=78 (3%) Other: n=77 (3%), Luxation: n=65 (2%), Muscle strain: n=66 (2%), Tendon strain: n= 35 (1%), Stress fracture: n=30 (1%), Bone fracture: n=22 (1%)	Not reported

Matos et al. (2020) B[18]	Self-reported injury	Daily surveyed over 52 weeks	Not reported	52% (13 runners reported at least one injury)	Not reported	Not reported	Total injuries: n=38 MSK:[b] n=33 Dermatological: n=5	Not reported	Time loss: 1-3 days: n=25 4-7 days: n=10 8-21 days: n=3
Viljoen et al. (2021)[19]	Self-reported	None	Retrospective annual incidence: 49.5 RRIs[d] /1000h of running.	Point prevalence of RRIs: 1.3% Annual prevalence of RRIs: 28.2% Total injuries (n=102)	Lower limb: n=89 (87.3%) Upper Limb: n=6 (5.6%) Trunk: n=6 (5.6%) Head and neck: n=1 (1.0%)	Knee: n=27 (26.5%), Ankle: n=22 (21.6%), Foot: n=17 (16.7%), Lower leg: n=12 (11.8%), Thigh: n=8 (7.8%), Lumbosacral: n=5 (4.9%), Shoulder: n=3 (2.9%), Hand: n=2 (2.0%), Hip/groin: n=2 (2.9%), Wrist: n=1 (1.0%), Head: n=1 (1.0%), Chest: n=1 (1.0%)	Muscle/tendon: n=45 (44.1%) Ligament/joint capsule: n=20 (19.6%) Cartilage/synovium/ bursa: n=14 (13.7%) Bone: n=10 (9.8%) Superficial tissues/skin: n=1 (1.0%) Nervous: n=2 (2.0%)	Tendinopathy: n=28 (27.5%), Joint sprain: n=20 (19.6%), Muscle injury: n=16 (15.7%), Synovitis/capsulitis: n=10 (9.8%), Fracture: n=5 (4.9%), Bone stress injury: n=5 (4.9%), Cartilage injury: n=3 (2.9%), Tendon rupture: n=1 (1.0%), Brain/concussion/spinal cord injury: n=1 (1.0%), Peripheral nerve injury: n=1 (1.0%), Bursitis: n=1 (1.0%), Laceration: n=1 (1.0%)	Average OSTRC [f] injury severity score: 31.6 (95% CI: 27.9-35.3)

a: Multistage ultramarathon
b: Musculoskeletal
c: interquartile range
d: RRI: Running related injury
e: Confidence interval
f: Oslo Sports Trauma Research Centre
g: Iliotibial band

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APPENDIX 10: Research Ethics Committee Aproval Certificate

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 22 May 2002 and Expires 03/20/2022.
- IORG #: IORG0001762 OMB No. 0990-0279 Approved for use through February 28, 2022 and Expires: 03/04/2023.

15 April 2021

Approval Certificate
Amendment

Ethics Reference No.: 469/2018
Title: DEVELOPMENT OF A TRAIL RUNNING INJURY SCREENING INSTRUMENT (TRISI)

Dear Mr CT Viljoen

The **Amendment** as supported by documents received between 2021-03-17 and 2021-04-14 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2021-04-14 as resolved by its quorate meeting.

Please note the following about your ethics approval:
- Please remember to use your protocol number (469/2018) 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

Professor Werdie (CW) Van Staden
MBChB MMed(Psych) MD FCPsych(SA) FTCL UPLM
***Chairperson**: Faculty of Health Sciences Research Ethics Committee*

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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