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Incidence, severity, and risk factors for injuries in female trail runners – A retrospective cross-sectional study

Morven Goodrum [a], Carel Viljoen [b], Kelly Kaulback [a,*]

[a] Faculty of Sport, Technology and Health Sciences, St Mary's University, London, UK
[b] Department of Physiotherapy, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa

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ABSTRACT

Objectives: To determine the incidence, severity, and nature of injuries sustained by female trail runners and investigate selected training variables as risk factors for injuries.
Design: Cross-sectional, retrospective cohort study.
Setting: Online questionnaire (Jisc Online Surveys).
Participants: Female trail runners (n = 62) aged 39.1 ± 12.4 years.
Main outcome measures: Training metrics (average weekly number of running sessions, mileage (km), session duration (mins), pace (min/km), ascent (m) and descent (m), number of running doubles per week, number of cross training doubles per week, type of cross training), incidence, severity and nature of trail running injuries sustained in the previous 12 months.
Results: The injury incidence was 14.3 injuries per 1000 h and mean severity score (OSTRC- H) was 80.95 ± 21.74. The main anatomical region affected was the lower limb (63.4%), primarily the ankle (13.9%), knee (13.0%) and lower leg (12.2%). The most common injury was tendinopathy (25.2%). A higher number of injuries sustained in the previous 12 months was weakly associated with a higher average duration of other (not trail) weekly running sessions (p = 0.017).
Conclusions: Findings from this study could inform future injury prevention and treatment strategies. Prospective, longitudinal data on injuries in female trail runners is needed.

1. Introduction

Trail running takes place in natural environments, with no more than 20% of running on paved roads (International Trail Running Association, 2021). In the United Kingdom (UK) a variety of trail running events between 10 and 100 km, with up to 13000m ascent, are hosted on a range of terrains including coastal paths, moorlands, river valleys, Pennines, and glaciated mountains (Montane Spine, 2023). However, the terrain, significant elevation changes, and environmental hazards increase the risk of injury (Viljoen et al., 2022).

Injury incidence in a living systematic review is reported collectively for males and females as 0.7–61.2 injuries per 1000 h of running (Viljoen et al., 2022). However, this review by Viljoen et al. (2022) acknowledges that participants were 80.8% male and highlighted the need for future studies to focus on injury among female trail runners.

Injuries associated with trail running are 83.3% lower limb, not dissimilar to other types of running (Viljoen et al., 2022). The most common pathologies are blisters followed by joint

sprains and Achilles tendinopathies (Lopes et al., 2012; Willwacher et al., 2022). Similarly to

other forms of running, patellofemoral pain syndrome and Iliotibial band (ITB) injuries are common (Lopes et al., 2012). Hollander et al. (2021) reported no difference in the injury

incidence between sexes for overall running-related injuries, but it is understood that female

runners are more likely to sustain bone stress injuries while male runners are more prone to.

Achilles tendinopathies. A limitation of this review was that both trail and road running studies were included. Biomechanical characteristics of female runners including increased hip adduction and rear foot eversion may increase the risk of running injury (Vannatta et al., 2020). Additionally, female hormones and relative energy deficiency in sport (RED-S) related risk factors such as amenorrhea could be why bone injuries are seen more frequently in female runners (Mountjoy et al.,

* Corresponding author. Faculty of Sport, Technology and Health Sciences, St Mary's University, London, UK.
E-mail address: kelly.kaulback@stmarys.ac.uk (K. Kaulback).

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2023).

Injury epidemiological literature on track and road running have reported that training variables such as increased weekly running distance, frequency of running sessions per week, and average running speed increase injury risk (Van der Worp et al., 2015). In trail running literature these variables have yet to show an association with injury risk (Malliaropoulos et al., 2015; Viljoen et al., 2021a, 2021b). More running experience and double training sessions have been reported as significant intrinsic and extrinsic risk factors respectively (Viljoen et al., 2022). However, study durations have been short (2 weeks) and injury definitions used have not been all-encompassing, increasing the likelihood of underreporting (Malliaropoulos et al., 2015; Viljoen et al., 2021a).

Despite a growing body of literature related to trail running injury, there is a lack of literature among female trail runners. It is known that the terrain and nature of trail running increases the risk for injury, but modifiable risk factors are unclear. Therefore, the aim of this study was to determine the incidence, severity, and nature of injuries sustained by female trail runners and to investigate selected modifiable training variables as risk factors for injuries in this population. Insight into female trail running injuries could inform future injury prevention and treatment strategies.

2. Methods

2.1. Study design and setting

The study used a cross-sectional, retrospective cohort design. The study was approved by St Mary's University Faculty of Sport, Technology, and Health Sciences Ethics Committee and all participants provided informed consent. Data were collected through a self-reported online survey hosted on Jisc Online Surveys (v2). Respondents were primarily located in the UK, as well as the United States (US) and Australia.

2.2. Participants and recruitment

Participants were recruited using a convenience sample, primarily by emailing trail running groups in the UK, US and Australia. The groups contacted were described as 'trail running' clubs as opposed to 'athletics' clubs. Selection was also based on whether the group had an email address available and responded within the 2 months of data collection.

Recruitment flyers were also posted in London-based trail running groups. Recruitment began in November 2023 and continued over 2 months of data collection.

2.3. Inclusion criteria were as follows

- Females aged 20–65 years
- Participation in trail running for at least 1 year running distances ranging from sub-marathon (minimum 5 km), marathon (42.2 km) or ultramarathon (>42.2 km)
- Train on 80% trails (unpaved paths)
- Residing in UK, US or Australia
- Access to the internet and email
- Fluent in English

Demographic questions within the survey allowed participants to confirm their age and sex. If 'male' or 'other' was selected for sex, participants were screened out of the survey. To ensure the criteria of 'trail' running was met, participants rated how frequently they trained on different surfaces (trail, street, grass, athletics track, and treadmill) using a 1–5 Likert scale (Viljoen et al., 2021a). If 'trail' was not selected as one of the top 2 surfaces, their survey was removed before analysis.

2.4. Survey development

Survey development was guided by the most recent International Olympic Committee consensus statement on sports injury and epidemiology (Bahr et al., 2020) and previously validated questionnaires including: 'The Orchard Sports Injury and Illness Clarification System' (OSIICS) (Orchard et al., 2020) for injury type and modified 'Oslo Sports Trauma Research Centre Questionnaire on Health Problems' (OSTRC-H) (Mashimo et al., 2021) for injury severity. Prior to the pilot study the survey was subject to face validity by the research supervisor.

Data collected were about trail running injuries sustained by participants in the previous 12 months. The survey consisted of 41 questions split into 4 sections: 1) Demographics, 2) Training data, 3) Injury type, and 4) Injury severity. If participants had multiple injuries to report, they completed the last two sections repeatedly for each injury. Question type included multiple choice single and multiple answer questions, selection lists, Likert scale and single-line open questions.

2.5. Pilot study

The questionnaire was piloted for two weeks in November 2022 before data collection began on January 1, 2023 until March 1, 2023. Participants of the pilot study were a convenience sample of University students. An important finding of the pilot study was that responses from multiple questionnaires for the same participant could not be merged. This was resolved using 'pre population parameters' in Jisc Online Surveys. The formatting of 'training data' questions were changed from 'open' to 'selection list' to improve accuracy of the data collected.

2.6. Definitions and reporting

2.6.1. Injury

'Injury' was defined in the questionnaire as: "*Tissue damage or other derangement of normal physical function due to participation in sports, resulting from rapid or repetitive transfer of kinetic energy*" (Bahr et al., 2020). Injury definition was based on the International Olympic Committee consensus statement where injury is an all-encompassing definition.

An all-encompassing definition was chosen as a time-loss injury definition can lead to under reporting (Bahr et al., 2020). There was also limited consensus on what defines 'time loss' for running (i.e., one session, 3 consecutive sessions) (Yamato et al., 2015). Additionally, the aim of the study was to determine the nature and severity of injuries which means that even injuries that are managed without time loss e.g., with reduced mileage, should be included to get an accurate understanding of the injury epidemiology in this population.

2.6.2. Injury incidence

Injury incidence was reported as the number injuries per 1000 h of running (Viljoen et al., 2021a) and calculated using the formula (Tenny & Boktor, 2022):

[Number of total injuries / Total person-time at risk] X sum of person-time

2.6.3. Total person-time at risk

Total person-time at risk was calculated by multiplying average weekly running pace (min/km) and average weekly running distance (km).

2.6.4. Injury type

Injury type was reported using The OSIICS as recommended in the International Olympic Committee consensus statement (Bahr et al., 2020).

2.6.5. Injury severity

Severity of injury was defined as: *'The number of days that have elapsed* *from the day after the onset of the incident to the day of the athlete's return to full participation in Athletics training'* (Bahr et al., 2020). Injury severity questions were based on the OSTRC-H severity score where a numerical value from 0 to 25 is given regarding how the injury affected training/race participation, training volume, running performance, or produced pain while running. A severity score out of 100 is calculated using the sum of the 4 questions. The higher the value, the more severe the injury. A mean OSTRC-H severity score was calculated per anatomical region using the formula:

Severity score per region / Number of injuries per region

(Clarsen et al., 2013)

2.7. Statistical analysis

Statistical analysis was carried out using IBM SPSS statistics 29 for Mac (IBM Corp, New York, USA). Complete data sets for 62 participants were included in the analysis.

Demographics including age (years), running experience (years), and weekly running exposure were reported with descriptive statistics: mean ± SD, median (IQR), and frequencies n (%). A Shapiro-Wilk's test was conducted to determine if data were normally distributed (<0.05). Analysis of training variables as risk factors was performed with a Spearman's rank order correlation. The dependent variables were number of injuries and severity score. The predictor variables were number of running sessions per week (trail, other), average weekly distance (km) (trail, other, combined), average weekly running pace (min/km) (trail, other, combined), average weekly ascent (m) (trail, other, combined), average weekly descent (m) (trail, other, combined), number of running doubles per week, and number of cross training doubles per week.

3. Results

3.1. Participant demographics and training exposure

Participants (n = 62) had an average age of 39.1 ± 12.4 years and most (n = 41, 67.2%) had >10 years trail running experience. On average participants ran (trail and 'other' combined) 3003 km over the 12-month surveillance period. Trail running experience and training exposure data are presented in Table 1.

All participants completed at least 2–3 trail running sessions per week whilst most participants (n = 28; 45.2 %) completed 4–5 trail running sessions per week. Most participants completed an additional 2–3 'other' running sessions per week (n = 32; 51.6%). Weekly trail running distance (51.05 km) and elevation (506.93m) were more than double that of 'other running' (20.25 km and 113.38m respectively). Average pace of all running was less than 4 min/km. Most participants reported not running 'doubles' (69.4%), although 11.3% reported running doubles 3–4 times per week. Strength training was the most common form of cross training although only 32 participants (51.6%) reported strength training. Cycling (n = 24), Pilates/yoga (n = 24), and swimming/aqua jogging (n = 19) were other common forms of cross-training. There were six participants who did not do any cross-training.

3.2. Injury incidence

The injury incidence was 14.3 injuries per 1000 h of running. A total of 115 injuries were reported. In each injury incidence there were a median of 15 training days missed and 18 training days modified in relation to injury. Injury incidence descriptives are reported in Table 2.

Most participants (41.9%) sustained two injuries over 12 months. Only one participant did not sustain an injury. Most of the injuries had a gradual onset (60.9%), occurred in training (82.6%), and were caused by a self-reported training error (54.8%).

Table 1
Trail running training exposure and experience for all participants.

Training Characteristic	Trail running Mean ± SD	Other[a] running Mean ± SD
Distance per week (km)	51.05 ± 25.3	20.25 ± 14.6
Duration per run (mins)	83.50 ± 24.0	54 ± 27.3
Average pace per run (min/km)	4.62 ± 0.8	4.44 ± 0.7
Average weekly ascent (m)	506.93 ± 188.2	113.38 ± 108.5
Average weekly descent (m)	494.14 ± 187.8	108.51 ± 104.1
Average RPE per session (Borg 0–10)	4.89 ± 0.7	5.61 ± 2.1
Weekly running frequency	**Trail running n (%)**	**Other[a] running n (%)**
None	–	7 (11.3)
1 session/week	–	22 (35.5)
2–3 sessions/week	26 (41.9)	32 (51.6)
4–5 sessions/week	28 (45.2)	1 (1.6)
6–7 sessions/week	8 (12.9)	–
Weekly running doubles[b]		
Never	43 (69.4)	
1–2 doubles/week	12 (19.4)	
3–4 doubles/week	7 (11.3)	
Weekly cross training doubles[c]		
Never	26 (41.9)	
1–2 cross-training doubles/week	29 (46.8)	
3–4 cross-training doubles/week	5 (8.1)	
5–6 cross-training doubles/week	2 (3.2)	
Weekly cross training single[d]		
Cycling	24 (38.7)	
1 session/week (n = 10, 41.7%)		
2 sessions/week (n = 12, 50.0%)		
3 sessions/week (n = 2, 8.3%)		
Strength training	32 (51.6)	
1 session/week (n = 5, 4.3%)		
2 sessions/week (n = 23, 19.8%)		
3 sessions/week (n = 4, 3.4%)		
Swimming/aqua jogging	19 (30.6)	
1 session/week (n = 4, 21.1%)		
2 sessions/week (n = 12, 63.2%)		
3 sessions/week (n = 2, 10.5%)		
5 sessions/week (n = 1, 5.3%)		
Pilates/yoga	24 (38.7)	
1 session/week (n = 12, 50.0%)		
2 sessions/week (n = 12, 50.0%)		
No cross-training	6 (9.6)	
Trail running experience		
1–2 years	2 (3.3)	
3–4 years	6 (9.8)	
5–7 years	7 (11.5)	
8–10 years	5 (8.2)	
>10 years	41 (67.2)	

[a] Other running sessions not completed on trail.
[b] Running twice in one day.
[c] Running and cross training on the same day.
[d] Cross training only (not combined with running).

3.3. Injury severity and nature

Injury nature, location, and severity is presented in Table 3. The main injury pathologies reported were tendinopathy (25.2%) followed by fasciitis (13.0%) and muscle strain (11.3%).

The mean severity score for all injuries was 80.95 ± 21.74. The lower

Table 2
Injury incidence descriptives.

Injury characteristic	n (%)
Frequency of injuries reported	
None	1 (1.6)
1 injury	22 (35.5)
2 injuries	26 (41.9)
3 injuries	12 (19.4)
4 injuries	1 (1.6)
Injury onset	
Gradual	70 (60.9)
Sudden	45 (39.1)
Injury history	
New	68 (59.1)
	47 (40.9)
Injury context	
Training	95 (82.6)
Competition	19 (16.5)
Other	1 (0.8)
Injury mechanism	
Training error[a]	63 (54.8)
Fall	18 (15.7)
Jump	1 (0.9)
Landing	3 (2.6)
Overstretch	7 (6.1)
Other	23 (20.0)
Diagnosis	
Doctor	13 (11.3)
Physiotherapist	70 (60.9)
Self-diagnosed	32 (27.8)
	Median (IQR)
Training days missed (per injury)	15 (6–25)
Training days modified (per injury)	18 (8–25)

[a] Self-reported error in training that led to injury e.g., increased mileage too quickly.

limb was the anatomical region most affected by injury (49.5%) followed by the hip/groin/pelvis (23.5%). The areas of the lower limb most affected by injury were the ankle (13.9%), knee (13%) and lower leg (12.2%). The lumbar spine had the highest severity score (99.0) for body area and the lower limb had the highest severity score for anatomical region (84.1), followed by the thigh (76.25).

3.4. *Association between injury prevalence, severity, and injury risk factors*

A Shapiro-Wilk test identified that injury and injury risk factor data were not normally distributed ($p < 0.05$). A Spearman's rank-order correlation was run to determine the relationship between the number of injuries sustained and injury risk factors, and the severity of injuries sustained and injury risk factors (Table 4).

The results showed a significant, weak positive correlation between a higher number of injuries sustained and a longer duration of other running sessions ($rs = 0.317$, $p < 0.05$).

4. Discussion

The aim of this study was to determine the incidence, severity, and nature of injuries sustained by female trail runners and to investigate selected training variables as risk factors for injuries in this population. The main findings were a) an injury incidence of 14.3 injuries per 1000 h, b) injuries had a high mean severity score, c) most injuries were in the lower limb, had a gradual onset, occurred in training, and were caused by a self-reported training error, and d) there was a weak association between number of injuries sustained and the average duration of other running sessions per week.

The injury incidence of this study (14.3 injuries per 1000 h) aligned with the broad injury incidence of 1.6–61.2 injuries in male and female runners reported by Viljoen et al. (2022). The mean severity score for all injuries of 80.95 ± 21.74 was significantly higher than the mean severity score - 31.6 (95% CI; 27.9–35.3) - reported by Viljoen et al. (2021c). The previously reported lower severity score may be related to the survey being part of a pre-race medical screening process and reporting of a severe injury would have resulted in disqualification, whereas this study had no consequence for severity reporting.

Table 3
Injury nature, location, and severity.

Injury nature	n (%)	Anatomical Region	Body Area	n	% Of All RRIs[a] (n = 115)	Mean OSTRC Severity Score[b]
Tendinosis/tendinopathy	29 (25.2)	**Upper limb**	**All**	**5**	**4.3**	**66.25**
Fasciitis/aponeurosis injury	15 (13.0)		Shoulder (including clavicle)	1	0.9	14.0
Muscle strain	13 (11.3)		Upper arm	1	0.9	100
Other bone injuries	9 (7.8)		Forearm	1	0.9	75.0
Other	7 (6.1)		Wrist	2	1.7	76.0
SIJ dysfunction	1 (0.9)					
Patellofemoral pain syndrome	4 (3.5)					
Shin splints	1 (0.9)					
Compartment Syndrome	1 (0.9)					
Muscle cramps or spasm	7 (6.1)	**Lumbar spine & abdomen**	**All**	**10**	**8.7**	**71.75**
Arthritis/synovitis/bursitis	6 (5.2)		Lumbar spine	8	7.0	99.0
Impingement	6 (5.2)		Abdomen	2	1.7	44.5
Contusion/haematoma/bruise	5 (4.3)	**Hip/groin/pelvis**	**All**	**27**	**23.5**	**72.85**
Sprain	5 (4.3)		Pelvis/buttock	6	5.2	68.0
Fracture	4 (3.5)		Hip/groin	21	18.3	77.7
Stress fracture	3 (2.6)	**Thigh**	**All**	**16**	**13.9**	**76.25**
Skin abrasion/chafing	2 (1.7)		Quadricep	11	9.6	77.5
			Hamstring	5	4.3	75.0
Muscle rupture/tear	1 (0.9)					
Skin laceration/cut/lesion	1 (0.9)	**Lower limb**	**All**	**57**	**49.5**	**84.1**
Tendon rupture	1 (0.9)		Knee	15	13.0	84.0
Unknown	1 (0.9)		Lower leg	14	12.2	82.3
			Ankle	16	13.9	90.5
			Foot/toes	12	10.4	79.6

[a] RRIs = running related injuries.
[b] Cumulative score of effect on participation in training/competition, performance, modification of training, and pain whilst running (0 = least severe–100 = most severe).

Table 4
Association between number of injuries, severity, and injury risk factors.

Risk factor	No. of injuries		Injury severity	
	r_s value	p value	r_s value	p value
No. running sessions per week				
Trail sessions	0.117	0.364	0.239	0.063
Other[a] sessions	0.148	0.252	−0.105	0.420
Distance per week (km)				
Trail	0.090	0.498	0.119	0.371
Other[a]	0.186	0.159	−0.158	0.233
Combined	0.127	0.336	0.031	0.813
Duration per week (mins)				
Trail	−0.101	0.436	0.040	0.762
Other[a]	0.317*	0.017*	−0.193	0.158
Combined	0.102	0.429	−0.059	0.649
Pace per week (min/km)				
Trail	−0.141	0.313	−0.025	0.858
Other[a]	−0.256	0.086	0.106	0.482
Combined	−0.176	0.208	0.069	0.625
Ascent per week (m)				
Trail	0.092	0.488	0.000	0.998
Other[a]	−0.007	0.966	0.066	0.677
Combined	0.117	0.488	0.005	0.969
Descent per week (m)				
Trail	0.090	0.499	0.017	0.896
Other[a]	−0.018	0.910	0.039	0.807
Combined	0.115	0.388	0.033	0.806
Weekly running doubles[b]	0.162	0.207	0.084	0.522
Weekly cross training doubles[c]	−0.112	0.388	0.160	0.218
Cross training sessions per week				
Cycling	0.002	0.994	0.164	0.455
Strength	0.173	0.343	0.202	0.276
Swimming/aqua jogging	0.175	0.473	0.268	0.267
Yoga/pilates	0.051	0.812	0.397	0.061

[a] Other running sessions not completed on trail.
[b] Running twice in one day.
[c] Running and cross training on the same day. *Correlation significant at the 0.05 level (2-tailed).

Additionally, only 30.1% of participants were female so the severity score might not have been representative of the severity of injuries in female trail runners specifically. In this study the highest mean severity score was reported for the lower limb (84.1); higher than the severity score for lower limb injuries (47.8) reported elsewhere (Viljoen et al., 2021a). A higher incidence of cumulative bone injuries (fractures, stress fractures and other bone injuries (n = 16, 13.9%) has likely led to the higher severity score and whilst not all of these occurred in the lower limb, it follows the narrative in road running literature of female runners being more likely to sustain bone stress injuries (Hollander et al., 2021).

The majority prevalence of injuries in the lower limb is similar to previous trail and road running literature and includes the ankle, knee and lower leg being areas most affected (Lopes et al., 2012; Viljoen et al., 2022). This result is consistent across trail and road running literature regardless of participant age (Sanchez-Garcia et al., 2022), participant experience (González- Lázaro et al., 2021), or study design (Scheer & Krabak, 2021; Viljoen et al., 2021a).

Tendinopathy was the most common injury pathology, followed by fasciitis and muscle strain. Although this study was self-reported and retrospective, this pathology finding gains reliability as most injuries were diagnosed by a physiotherapist. Tendinopathies were also the most reported pathologies (27.8%) in a study of South African trail runners by Viljoen et al. (2021a), followed by muscle injuries (20.5%) and joint sprains (8.8%). Similarly, Hespanhol et al. (2017) reported the most common pathologies as Achilles tendon injury (12.8%) and calf muscle injury (10.7%). A high incidence of muscle injuries and tendinopathies in trail running is likely due to high volumes of eccentric muscle work, especially in downhill running (Viljoen et al., 2021b). Trail running is also usually of long duration which lends itself to development of chronic overuse injuries such as tendinopathy (Chang Chien et al., 2022). This is further supported by 60.3% of injuries in this study being gradual rather than sudden onset and most injuries resulting from self-reported training errors, such as a sudden increase in load, which aligns with risk factors for tendinopathies (Aicale et al., 2018). Elevation changes also expose the calf to significant load for a sustained period which can additionally overload the Achilles (Viljoen et al., 2021b). Subtle variations in the site and pathologies of injuries in the previously mentioned studies may be due to variability in running environments and elevations seen in trail running, resulting in different loading patterns (Viljoen et al., 2021a).

However, a study of recreational male (n = 529) and female (n = 190) trail runners by Matos et al. (2020) found sprains (11%) were the most common pathology with only 4% of pathologies being tendinopathies. Sprains are common in trail running due to running on uneven terrain with high levels of fatigue (Viljoen et al., 2021b). The high rates of ankle sprains in previous reports could have been the result of participants average trail running experience being 3.40 ± 2.37 years compared to this study in which 67.2% had >10 years trail running experience. Thus, participants may have been poorly conditioned to the technical, uneven terrain. However, Sanchez-Garcia et al. (2022) also reported joint sprains made up nearly half of injury pathologies (43.2%) amongst young elite male and female trail runners. Whilst tendinopathies are common in trail running at the ultra-marathon (UM) distance (Krabak et al., 2011), patellofemoral pain syndrome is more common in single, multiday, and timed UM events (Scheer & Krabak, 2021). This is possibly explained by the high levels of fatigue associated with UM events which can alter knee joint kinematics, increasing vertical ground reaction forces within the knee joint (Viljoen et al., 2021b).

A weak association was found between number of injuries sustained and the average duration of other (not trail) running sessions per week. No other associations were found between injury number or severity and other training variables. Malliaropoulos et al. (2015) also found no association between training variables (kilometres run per week and double training sessions per week) and injury prevalence. In contrast, a higher number of running sessions, total running distance, and a higher biweekly number of running sessions was associated with significantly lower odds of sustaining an injury among South African trail runners (Viljoen et al., 2021a). It appears injury risk factors are inconclusive. Differences in reported risks and injury prevalence could be attributed to the differences in study design and injury definitions. It is also unlikely that injuries in trail running are due to a single variable and lack of statistical significance doesn't necessarily mean that these variables aren't of clinical relevance (Viljoen et al., 2022).

Similarly to previous trail running (Hespanhol et al., 2017; Scheer & Krabak, 2021) and road running literature (Hollander et al., 2021; Lopes et al., 2012; Van der Worp et al., 2015), most injuries in this study had a gradual rather than sudden onset, This is understandable given the repetitive micro-trauma that would result from withstanding forces 3-4 x bodyweight for a sustained period (Hespanhol et al., 2017; Willwacher et al., 2022). From this study, the combination of most injuries having a gradual onset, occurring during training, because of self-reported training error, is clinically and practically notable.

4.1. Strengths and limitations

The study had a relatively small sample size of 62 participants reducing external validity and statistical power of the study (Bahr et al., 2003). Recall bias was a limitation of the study as participants may have been reporting training data from memory rather than GPS devices. Additionally, the retrospective, cross sectional design of the study further increased the chances of recall bias. Participants in this study were primarily based in the UK as well as the US and Australia so these results should not be generalised to a global trail running population due to the unique environments and training habits that trail runners in different regions may be exposed to. Furthermore, risk factors for trail running injury are multifactorial (Viljoen et al., 2022), but only a specific category of extrinsic risk factors was explored in this study. Adding to this, the training data gathered from participants was an average over 12-months, so did not consider increasess in training volume and intensity which may have had an association with the injury data reported. As we used self-reported injury data, our findings regarding specific pathologies need to be interpreted with caution as we could not clinically confirm the reported pathology detail.

4.2. Clinical application and recommendations

Findings from this study could inform future injury prevention and treatment strategies but prospective, longitudinal data on injuries in female trail runners is needed. However, there is clinical relevance in the summation that most injuries were of high severity, sustained during training, because of training errors. This prompts coaches and athletes to review their training strategy and implement appropriate load management and periodisation. Future research should focus on conducting prospective study designs with a long follow-up and explore injury prevention strategies including systematic load management and strength training, particularly as only 50% of the study participants participated in strength training. There remains limited research into the female trail running population.

5. Conclusion

Injury incidence and severity amongst female trail runners were high, and higher than previously published literature. This study found the lower limb was the anatomical region most affected by injury with tendinopathy being the most common pathology, not dissimilar to other trail running literature. The disparity between studies reporting the incidence, severity and nature of trail running injuries is likely due to differences in study design as well as participant demographics. Further research is required to understand injury epidemiology within a female trail running population as well as risk factors associated with injury risk within this population. This will enable appropriate education, injury prevention, and training strategies to be implemented.

CRediT authorship contribution statement

Morven Goodrum: Writing – original draft, Conceptualization. **Carel Viljoen:** Writing – review & editing. **Kelly Kaulback:** Writing – review & editing, Supervision.

Ethical approval

The study was approved by St Mary's University Faculty of Sport, Technology, and Health Sciences Ethics Committee and all participants provided informed consent.

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Declaration of competing interest

None declared.

References

Aicale, R., Tarantino, D., & Maffulli, N. (2018). Overuse injuries in sport: A comprehensive overview. *Journal of Orthopaedic Surgery and Research, 13*(309), 1–11. https://doi.org/10.1186/s13018-018-1017-5

International Olympic Committee Injury and Illness Epidemiology Consensus Group, Bahr, R., Clarsen, B., Derman, W., Dvorak, J., Emery, C. A., … Chamari, K. (2020). International olympic committee consensus statement: Methods for recording and reporting of epidemiological data on injury and illness in sports 2020 (including the STROBE extension for sports injury and illness surveillance (STROBE-SIIS)). *Orthopaedic Journal of Sports Medicine, 8*(2), Article 2325967120902908. https://doi.org/10.1177/2325967120902908

Bahr, R., & Holme, I. (2003). Risk factors for sports injuries—a methodological approach. *British Journal of Sports Medicine, 37*(5), 384–392. https://doi.org/10.1136/bjsm.37.5.384

Chang Chien, G. C., Zhang, A., & Chapman, K. B. (2022). Tendinopathy. In *Regenerative medicine: A complete guide for musculoskeletal and spine disorders* (pp. 217–230). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-75517-1_22.

Clarsen, B., Myklebust, G., & Bahr, R. (2013). Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports trauma research Centre (OSTRC) overuse injury questionnaire. *British Journal of Sports Medicine, 47*(8), 495–502. https://doi.org/10.1136/bjsports-2012-091524

González-Lázaro, J., Arribas-Cubero, H. F., & Rodríguez-Marroyo, J. A. (2021). Muskuloskeletal injuries in mountain running races: A 5 seasons study. *Injury, 52*(4), 747–749. https://doi.org/10.1016/j.injury.2020.10.045

Hespanhol Junior, L. C., Van Mechelen, W., & Verhagen, E. (2017). Health and economic burden of running-related injuries in Dutch trailrunners: A prospective cohort study. *Sports Medicine, 47*, 367–377. https://doi.org/10.1007/s40279-016-0551-8

Hollander, K., Rahlf, A. L., Wilke, J., Edler, C., Steib, S., Junge, A., & Zech, A. (2021). Sex-specific differences in running injuries: A systematic review with meta-analysis and meta-regression. *Sports Medicine, 51*, 1011–1039. https://doi.org/10.1007/s40279-020-01412-7

International Trail Running Association. (2021). Trail racing: An off-road experience. *International Trail Running Association*. https://www.itra.run/About/DiscoverTrailRunning Accessed on 14 November 2024.

Krabak, B. J., Waite, B., & Schiff, M. A. (2011). Study of injury and illness rates in multiday ultramarathon runners. *Medicine & Science in Sports & Exercise, 43*(12), 2314–2320.

Lopes, A. D., Hespanhol, L. C., Yeung, S. S., & Costa, L. O. P. (2012). What are the main running- related musculoskeletal injuries? *Sports Medicine, 42*(10), 891–905. https://doi.org/10.1007/BF03262301

Malliaropoulos, N., Mertyri, D., & Tsaklis, P. (2015). Prevalence of injury in ultra trail running. *Human Movement, 16*(2), 55–59. https://doi.org/10.1515/humo-2015-0026

Mashimo, S., Yoshida, N., Hogan, T., Takegami, A., Nishida, S., & Nagano, Y. (2021). An update of the Japanese Oslo Sports Trauma Research Center questionnaires on overuse injuries and health problems. *PLoS One, 16*(4), Article e0249685. https://doi.org/10.1371/journal.pone.0249685

Matos, S., Silva, B., Clemente, F. M., & Pereira, J. (2020). Running-related injuries in Portuguese trail runners: A retrospective cohort study. *The Journal of Sports Medicine and Physical Fitness, 61*(3), 420–427.

Montane Spine. (2023). *Montane spine expedition races*. Montane Spine. https://www.thespinerace.com.

Mountjoy, M., Ackerman, K. E., Bailey, D. M., Burke, L. M., Constantini, N., Hackney, A. C., Heikura, I. A., Melin, A., Pensgaard, A. M., Stellingwerff, T., Sundgot-Borgen, J. K., Torstveit, M. K., Jacobsen, A. U., Verhagen, E., Budgett, R., Engebretsen, U., & Erdener, U. (2023). 2023 international olympic committee's (IOC) consensus statement on relative energy deficiency in sport (REDs). *British Journal of Sports Medicine, 57*(17), 1073–1097. https://doi.org/10.1136/bjsports-2023-106994

Orchard, J. W., Meeuwisse, W., Derman, W., Hägglund, M., Soligard, T., Schwellnus, M., & Bahr, R. (2020). Sport medicine diagnostic coding system (SMDCS) and the orchard sports injury and illness classification system (OSIICS): Revised 2020 consensus versions. *British Journal of Sports Medicine, 54*(7), 397–401. https://doi.org/10.1136/bjsports-2019-101921

Sanchez-Garcia, L. F., Penichet-Tomas, A., Pueo, B., & Jimenez-Olmedo, J. M. (2022). Injury incidence and pattern in elite young male and female trail runners. *Applied Sciences, 12*(3), 1155. https://doi.org/10.3390/app12031155

Scheer, V., & Krabak, B. J. (2021). Musculoskeletal injuries in ultra-endurance running: A scoping review. *Frontiers in Physiology, 12*, Article 664071. https://doi.org/10.3389/fphys.2021.664071

Tenny, S., & Boktor, S. W. (2022). *Incidence. In StatPearls [internet]*. StatPearls Publishing.

Van der Worp, M. P., Ten Haaf, D. S., van Cingel, R., de Wijer, A., Nijhuis-van der Sanden, M. W., & Staal, J. B. (2015). Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One, 10*(2), Article e0114937. https://doi.org/10.1371/journal.pone.0114937

Vannatta, C. N., Heinert, B. L., & Kernozek, T. W. (2020). Biomechanical risk factors for running- related injury differ by sample population: A systematic review and meta-analysis. *Clinical Biomechanics, 75*, Article 104991. https://doi.org/10.1177/0363546513520295

Viljoen, C. T., Janse van Rensburg, D. C., Verhagen, E., Van Mechelen, W., Korkie, E., & Botha, T. (2021a). Epidemiology, clinical characteristics, and risk factors for running-related injuries among South African trail runners. *International Journal of Environmental Research and Public Health, 18*(23), Article 12620. https://doi.org/10.3390/ijerph182312620

Viljoen, C. T., Janse van Rensburg, D. C., Verhagen, E., Van Mechelen, W., Tomás, R., Schoeman, M., … Korkie, E. (2021b). Epidemiology of injury and illness among trail runners: A systematic review. *Sports Medicine, 51*, 917–943. https://doi.org/10.1007/s40279-020-01418-1

Viljoen, C., van Rensburg, D. C. C. J., Van Mechelen, W., Verhagen, E., Silva, B., Scheer, V., Besomi, M., Gajardo-Burgos, R., Matos, S., Schoeman, M., Van Rensburg, J. A., Van Dyk, N., Scheepers, S., & Botha, T. (2022). Trail running injury

risk factors: A living systematic review. *British Journal of Sports Medicine, 56*(10), 577–587. https://doi.org/10.1136/bjsports-2021-104858
Viljoen, C. T., van Rensburg, D. C. C. J., van Rensburg, A. J., Booysen, E., Chauke, S., Coetzee, P., … Cronje, T. (2021c). One in four trail running race entrants sustained an injury in the 12 months training preceding the 2019 SkyRun race. *Physical Therapy in Sport, 47*, 120–126. https://doi.org/10.1016/j.ptsp.2020.11.029
Willwacher, S., Kurz, M., Robbin, J., Thelen, M., Hamill, J., Kelly, L., & Mai, P. (2022). Running- related biomechanical risk factors for overuse injuries in distance runners: A systematic review considering injury specificity and the potentials for future research. *Sports Medicine*, 1–15. https://doi.org/10.1007/s40279-022-01666-3
Yamato, T. P., Saragiotto, B. T., & Lopes, A. D. (2015). A consensus definition of running-related injury in recreational runners: A modified delphi approach. *Journal of Orthopaedic & Sports Physical Therapy, 45*(5), 375–380. https://www.jospt.org/doi/10.2519/jospt.2015.5741.