# One in four trail running race entrants sustained an injury in the 12 months training preceding the 2019 SkyRun race

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## Highlights

- One in four trail runners sustain an RRI in the 12 months prior to race participation.
- Predominantly the lower limb is injured among trail runners, specifically the knee, ankle and foot.
- Muscle/tendon is mainly injured, with tendinopathies the most common pathology type among trail runners.

## ABSTRACT

**Objective:** To determine the epidemiology and clinical characteristics of RRIs among trail runners who entered the 2019 SkyRun races.

**Design:** Descriptive cross-sectional study

**Setting:** 2019 SkyRun races

**Participants:** Consent for data analysis was given by 305 of 412 (74%) race entrants.

**Main Outcome Measures:** Retrospective annual incidence (RRIs/1000 hours), point prevalence (%), frequency (%), characteristics (anatomical region, body area, tissue type, pathology type) and injury severity (mean severity score; 95% CI) of RRIs.

**Results:** 28.2% of participants reported at least one RRI. The retrospective annual incidence was 49.5/1000 hours and the point prevalence was 1.3%. Most injuries occurred in the lower limb (87.3%), with the knee (26.5%), ankle (21.6%), and foot (16.7%) reported as the most frequently injured body areas. Muscle/tendon accounted for 44.1% of tissue type injuries. Tendinopathy (27.5%), joint sprain (19.6%), and muscle injury (15.7%) were the most common pathology types reported. The mean injury severity score was 31.6.

**Conclusions:** One in 4 trail runners reported at least one RRI in the 12 months leading up to a race. RRIs mostly affected the lower limb specifically the knee, ankle and foot. Future research should establish injury risk factors to ultimately develop specific injury prevention strategies.

**KEYWORDS**

Trail running, Running-related injuries, Epidemiology, clinical characteristics

## INTRODUCTION

Running is a cost-effective mode of physical activity that plays a role in the prevention of lifestyle diseases and premature mortality.[1] Trail running is a form of physical activity that involves running outdoors on a variety of natural terrains (mountain, desert, forest) where runners are exposed to large elevation changes as presented by the specific natural environment.[2] Irrespective of the health benefits, running still has a high risk of injury.[3-5]

Among recreational road runners an incidence of 7.7 injuries per 1000 hours were reported with a significantly higher incidence of 17.8 injuries per 1000 hours among novice runners.[3] The knee (28%) was reported as the most common body area injured among road runners.[6] Cross country runners presented with an incidence of 13.1 injuries per 1000 athletic exposures (training session or event) in a 15-year longitudinal study,[7] with the lower leg reported as the most commonly injured body area among both male (35.2%) and female (23.5%) collegiate student cross country athletes.[8] With regards to trail running, several studies have focussed on medical encounters related to trail running race participation,[9-14] with only a limited number of studies that investigated training related injury outcomes.[15] A prospective cohort study among Dutch trail runners reported a mean prevalence of 22.4% for running related injuries (RRIs) sustained during two-weekly follow up periods.[15] The most common anatomical region of injury was the lower leg (20.6%), followed by the knee (18.9%), and foot (14.9%), with muscle (27.7%) and tendon (23.6%) reported as the most common tissue types affected.[15] These results, although adding to the literature pool, cannot be generalised to the global trail running population as the Netherlands has a unique landscape characterised by limited elevation changes.

Injury risk factors in trail running are not well studied. A study on Greek trail runners using a small sample size (n=40),[16] reported that participants with physical labour occupations, multiple

running sessions per day and more running experience were associated with a higher risk for injury.[16] Studies on conventional forms of running include injury risk factors such as body mass index (BMI),[17-19] sex[20,21] age,[18,19] and running experience.[18,19,22] Whether these factors will relate to a higher risk for injury among trail runners requires investigation. As trail running is often hosted in mountainous regions with varying natural running surfaces i.e. narrow single-track or dirt track off-road trails,[23] factors such as elevation change (steep ascent and descent) and trail running experience need to be investigated as potential injury risk factors among this population.

Certain trail running races, such as the SkyRun in South Africa, are hosted in elevated and remote settings where medical support is extremely challenging with limited resources.[24] Injured runners that are unable to continue running can be exposed to extreme weather conditions and environmental hazards[24] while awaiting medical support. This emphasises the need to establish injury risk factors with the intention to design specific injury prevention strategies, as the recurrence of an injury during a trail run race may have dire consequences.

This study aimed to investigate the epidemiology and clinical characteristics of RRIs among trail runners during the 12 months leading up to the 2019 SkyRun race. We further aimed to determine a potential association between commonly known injury risk factors in running and trail running specific variables.

## METHODS

### Study design

This study used a cross-sectional study design investigating data collected in the two weeks prior to the 2019 SkyRun race.

Participants and data collection

This study formed part of a larger project: "Reducing Injuries and Illness at Adventure Sports Events: A 10-Year Longitudinal Study (2018 - 2028)" (REC: 460/2018) that was approved by the Research Ethics Committee of the University of Pretoria. This specific study was also approved by the Research Ethics Committee of the University of Pretoria (REC:747/2019).

The population studied were trail runners that entered for the 2019 SkyRun race (38km, 65km or 100km) in South Africa. All trail runners completed a compulsory online pre-race medical screening questionnaire, two weeks prior to the race. The race regulations stipulated that in order to participate in the 2019 SkyRun race, each runner's information needed to be screened by a medical doctor to identify those at higher risk for developing health problems during the race. Trail runners volunteering to partake in the research signed consent that their de-identified data may be used.

Data collected included the trail runners' demographic profile (age, height, weight, BMI, running experience), training variables (weekly running frequency, weekly running distance, average running pace, running surface, cross-training, running experience, vertical gain, running shoes), injury history (current RRI, RRI in the past 12 months, severity of injury, clinical characteristics of injury), illness history (current illness, chronic disease) and medication use (current, chronic medication). For the purpose of this study, only the injury-related data were analysed. The questions related to demographics and training variables were based on questionnaires previously used in literature that investigated RRIs.[17,25] If a race entrant reported "yes" to sustaining one or multiple RRIs in the past 12 months then further questions were asked based on the four key questions of the Oslo Sports Trauma Research Center Questionnaire on Health Problems (OSTRC-H),[26] similar to former literature reporting cross-sectional data on sporting injuries.[27] The questions that focused on the clinical characteristics of injuries were similar to those used in a previous study by Anderson et al (2013).[28] In their study,

the runner was given a list of options to choose from under the categories of "injury location?", "injury type?", "have you had this injury before?", and "injury onset?".[28]

Study outcomes reported

We reported on the retrospective annual incidence (RRIs per 1000 hours), point prevalence (% of current injured participants), and frequency (n, %) of RRI characteristics (anatomical region, body area, tissue type, pathology type) in accordance with the 2020 International Olympic Committee (IOC) consensus guidelines for recording and reporting of epidemiological data on sports injuries.[29] All injuries were reported, i.e. one runner could report more than one injury. Injury severity (OSTRC-H mean severity score; 95% CI) was reported according to the OSTRC-H severity score, a numerical value (0-25) given to each response on four key questions regarding how injury affected the following: 1) training/race participation, 2) training volume, 3) running performance, or 4) produce pain while running, that added up to 100.[26] A score of 0 indicates that the specific injury had no effect on the key question, whereas a score of 25 indicate maximum effect.[26] The scoring was similar for questions 1 and 4: A=0, B=8, C=17, D=25, while questions 2 and 3 were scored as: A=0, B=6, C=13, D=19, E=25.[26] No categories of injury severity are stipulated in the OSTRC-H score, but a higher OSTRC-H severity score implies a higher severity of injury.[26] The variables of age, sex, BMI, average weekly running distance, average weekly vertical gain, total years of active running, total years of active trail running, average number of any running sessions per week, and average number of trail running sessions per week were analysed as potential associated injury risk factors (p-values).

Statistical analysis

The Pearson's Chi-Squared test was used to compare categorial variables of all race entrants versus consenting race entrants to determine if our sample was representative of the population (all 2019 SkuRyn race entrants). Descriptive statistics for the frequencies (%) of injury for anatomical region, body area, tissue type and pathology type were used. Inferential statistics

(Pearson's Chi-Squared test and Mann Whitney U test) were used to compare the demographic and training information of participants between injured and non-injured participants in order to investigate and identify possible associated injury risk factors. Effect sizes were added in order to record the magnitude of the reported effects. Participants were grouped into these two categories by considering which participants experienced a RRI during the past 12 months vs. those who did not. Pearson's Chi-Squared test was used when comparing categorical variables. The Shapiro-Wilk normality test was used to test if the continuous variable (BMI) was normally distributed and prompted the use of the non-parametric Mann Whitney U test for comparison between the groups, since the majority of the variables were not normally distributed. Since none of the univariate investigations yielded statistically significant results ($p<0.05$), a multivariate analysis was not considered.

## RESULTS

### Demographics of trail runners

A total of 412 trail runners entered the 2019 SkyRun race and 305 trail runners (74.0%) gave consent for their data to be analysed in this study [100km (n=193), 65km (n=92), 38km (n=30)]. An analysis was done to determine if our sample of consenting trail runners were representative of all race entrants with regards to the sex and race distance category (Table 1). The age group categories for all trail run entrants were not publicly available on the race website, and therefore analysis to compare all trail runners with consenting trail runners on this variable was not possible.

**Table 1: Characteristics (sex, race distance) of all trail run race entrants and consenting entrants**

| Characteristics | | All trail run entrants (n=412) | | Trail runners consenting as study participants (n=305) | | p-value |
|---|---|---|---|---|---|---|
| | | n | % of all entrants | n | % of study participants | |
| Sex | Males | 299 | 72.6 | 213 | 69.8 | 0.4726 |
| | Females | 113 | 27.4 | 92 | 30.2 | |
| Race Distance | 38km | 48 | 11.7 | 30 | 9.8 | 0.7414 |
| | 65km | 121 | 29.4 | 92 | 30.2 | |
| | 100km | 243 | 59.0 | 183 | 60.0 | |

Table 1 confirms that there was no statistically significant difference between the consenting trail runners and all race entrants in the sex (p=0.4726) and race distance categories (p=0.7414), indicating a representative study sample. The majority of consenting trail runners were males (69.8%, n=213), entered for the 100km race category (60.0%, n=183), and were in the 31 to ≤40 year age group (46.7%, n=142).

**Table 2: Characteristics of age (years), height (cm), weight (kg) and BMI (kg/m$^2$) of the three race distance categories (38 km, 65 km, 100 km)**

| Characteristic | | All consenting race entrants (n=305) Mean (95% CI) | 38 km (n=30) Mean (95% CI) | 65 km (n=92) Mean (95% CI) | 100 km (n=183) Mean (95% CI) |
|---|---|---|---|---|---|
| Age (years) Missing (n=0) | All | 38.3 (37.4-39.2) | 35.6 (32.4-38.9) | 37.9 (36.1-39.7) | 38.9 (37.8-40.0) |
| | Males | 38.7 (37.6-39.8) | 36.6 (30.4-42.7) | 38.0 (35.6-40.2) | 39.3 (38.0-40.5) |
| | Females | 37.3 (35.7-38.8) | 34.8 (32.3-37.3) | 37.8 (35.1-40.5) | 37.8 (35.4-40.2) |
| Height (cm) Missing (n=2) | All | 177.2 (176.1-178.2) | 173.0 (169.9-176.2) | 175.3 (171.0-179.6) | 177.8 (176.5-179.2) |
| | Males | 181.4 (180.4-182.3) | 178.4 (174.1-182.8) | 182.7 (180.8-184.5) | 181.2 (180.0-182.3) |
| | Females | 167.1 (165.8-168.5) | 168.3 (165.8-170.9) | 167.7 (165.7-169.7) | 166.2 (163.9-168.5) |

| | | | | | |
|---|---|---|---|---|---|
| Weight (kg) Missing (n=1) | All | 75.3 (73.9-76.8) | 72.1 (67.7-76.4) | 75.5 (72.7-78.3) | 75.7 (73.9-77.6) |
| | Males | 81.1 (79.7-82.4) | 78.6 (73.2-83.9) | 83.1 (80.5-85.7) | 80.5 (78.8-82.1) |
| | Females | 61.9 (60.3-63.5) | 66.4 (61.5-71.4) | 62.5 (60.0-65.0) | 59.6 (57.8-61.4) |
| BMI ($kg/m^2$) Missing (n=2) | All | 23.9 (23.6-24.2) | 24.0 (22.9-25.1) | 23.9 (23.3-24.5) | 23.9 (23.5-24.3) |
| | Males | 22.2 (21.7-22.6) | 24.7 (23.2-26.1) | 24.9 (24.2-25.6) | 24.5 (24.1-24.9) |
| | Females | 24.6 (24.3-25.0) | 24.6 (24.3 - 25.0) | 22.2 (21.4-22.9) | 21.6 (21.1-22.1) |

CI: Confidence Interval
BMI: Body Mass Index

As observed in Table 2 the 100 km consenting trail runners had the highest mean age (38.9 years), height (177.8 cm), and weight (75.7 kg). Among all consenting trail runners for the different race distances had similar mean BMI measurements (38km=24.0 $kg/m^2$; 65km=23.9 $kg/m^2$; 100km=23.9 $kg/m^2$). On average, males reported a higher age (38.7 years), height (181.4 cm) and weight (81.1 kg), compared to females. Females on average presented with a higher BMI (24.6 $kg/m^2$).

Running surface exposure

Across all race distances, consenting race entrants trained most often on dirt roads (trails) (n=237; 76.5%) followed by street (tarred/paved) surfaces (n=173; 55.8%). The surfaces least often trained on were treadmills (n=17; 5.5%) and athletic tracks (tartan) (n=10; 3.2%) (Figure 1).

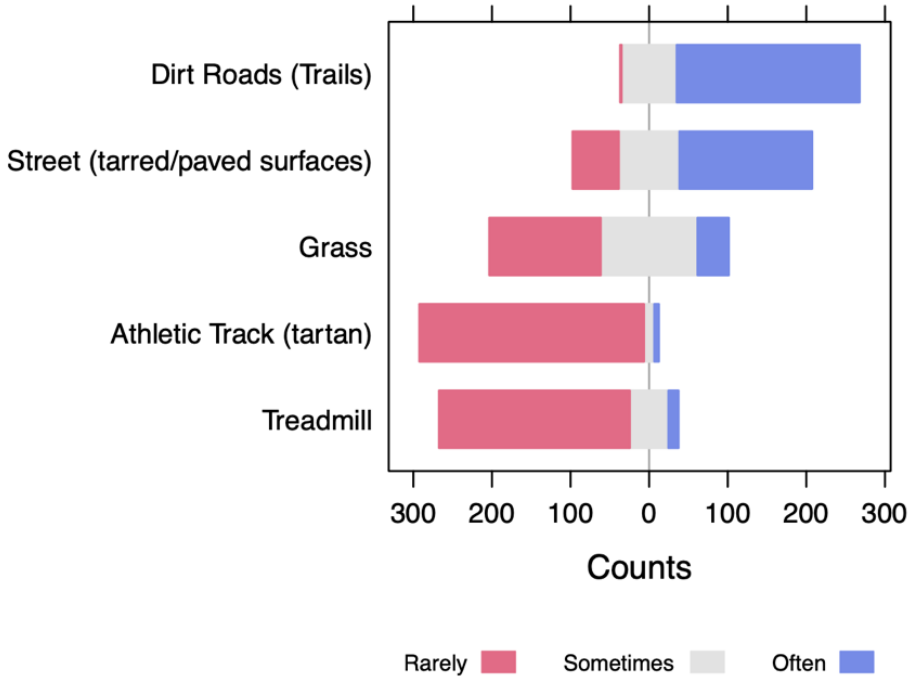


**Figure 1: The frequency (n) of reported running surfaces trained on often, sometimes, and rarely by consenting race entrants**

Epidemiology (retrospective annual incidence and point prevalence) of RRIs among consenting trail runners

The retrospective annual incidence was calculated at 49.5 RRIs per 1000 hours of running. Among the 305 consenting trail runners, 86 (28.2%) reported an RRI with 16 (5.2%) of these reporting multiple RRIs in the 12 months prior to the race. A total of 102 RRIs were reported of which only four consenting trail runners had a current injury at the time of race entry. The point prevalence of RRIs was 1.3%.

Clinical characteristics of RRIs among the consenting trail runners in the past 12 months

The clinical characteristics of RRIs are presented in the categories of injured anatomical region, body area, tissue type, pathology type, and injury severity.

Table 3 depicts the number (n) and frequencies (%) of RRIs (anatomical region, body area) in the past 12 months prior to the race across all race distance categories.

**Table 3: RRIs among consenting trail runners by anatomical region and specific body area (% RRIs) (n=102)**

| Anatomical region | Body area | All consenting race entrants | | Males | | Females | |
|---|---|---|---|---|---|---|---|
| | | Number of RRI (n=102) | % of all RRIs | Number of RRI (n=66) | % of all RRIs | Number of RRI (n=36) | % of all RRIs |
| Head and neck | **All** | **1** | **1.0** | **-** | **-** | **1** | **2.8** |
| | Head | 1 | 1.0 | - | - | 1 | 2.8 |
| Upper Limb | **All** | **6** | **5.6** | **1** | **1.5** | **5** | **13.9** |
| | Shoulder | 3 | 2.9 | - | - | 3 | 8,3 |
| | Wrist | 1 | 1.0 | - | - | 1 | 2.8 |
| | Hand | 2 | 2.0 | 1 | 1.5 | 1 | 2.8 |
| Trunk | **All** | **6** | **5.6** | **2** | **3.0** | **4** | **11.1** |
| | Chest | 1 | 1.0 | - | - | 1 | 2.8 |
| | Lumbosacral | 5 | 4.9 | 2 | 3.0 | 3 | 8.3 |
| Lower Limb | **All** | **89** | **87.3** | **63** | **95.5** | **26** | **72.2** |
| | Hip/groin | 3 | 2.9 | 1 | 1.5 | 2 | 5.6 |
| | Thigh | 8 | 7.8 | 4 | 6.1 | 4 | 11.1 |
| | Knee | 27 | 26.5 | 20 | 30.3 | 7 | 19.4 |
| | Lower leg | 12 | 11.8 | 12 | 18.2 | - | - |
| | Ankle | 22 | 21.6 | 14 | 21.2 | 8 | 22.2 |
| | Foot | 17 | 16.7 | 12 | 18.2 | 5 | 13.9 |

The anatomical region predominantly affected by RRIs was the lower limb (All: 87.3%, n=89; Males: 95.5%, n=63: Females: 72.2%, n=26) with the trunk (All: 5.6%, n=6; Males: 3.0%, n=2; Females: 11.1%, n=4) and upper limb (All: 5.6%, n=6; Males: 1.5%, n=1; Females: 13.9%, n=5) reported less frequently. The main injured body areas were the knee (All: 26.5%, n=27; Males: 30.3%, n=20; Females: 19.4%, n=7), ankle (All: 21.6%, n=22; Males: 21.2%, n=14; Females: 22.2%, n=8), and foot (All: 16.7%, n=17; Males: 18.2%, n=12; Females: 13.9%, n=5).

Table 4 depicts the number (n) and frequencies (%) of RRIs (tissue and pathology type) in the past 12 months prior to the race across all three race distance categories. Of the 102 self-reported injuries, 73.5% (n=75) were diagnosed by health care clinicians (medical doctors: 23.5%, n=24; physical therapists: 50%, n=51).

**Table 4: RRIs among consenting trail runners by tissue and pathology type (% RRIs) (n=102)**

| Tissue type | Pathology type | All consenting race entrants | | Males | | Females | |
|---|---|---|---|---|---|---|---|
| | | Number of RRIs (n=102) | % of all RRIs | Number of RRIs (n=66) | % of all RRIs | Number of RRIs (n=36) | % of all RRIs |
| Muscle/Tendon | **All** | **45** | **44.1** | **28** | **27.5** | **17** | **16.7** |
| | Muscle injury | 16 | 15.7 | 11 | 10.8 | 5 | 4.9 |
| | Tendinopathy | 28 | 27.5 | 16 | 15.7 | 12 | 11.8 |
| | Tendon rupture | 1 | 1.0 | 1 | 1.0 | - | - |
| Nervous | **All** | **2** | **2.0** | **-** | **-** | **2** | **2.0** |
| | Brain/Concussion or Spinal cord injury | 1 | 1.0 | - | - | 1 | 1.0 |
| | Peripheral nerve injury | 1 | 1.0 | - | - | 1 | 1.0 |
| Bone | **All** | **10** | **9.8** | **5** | **4.9** | **5** | **4.9** |
| | Fracture | 5 | 4.9 | - | - | 5 | 4.9 |
| | Bone stress injury | 5 | 4.9 | 5 | 4.9 | - | - |
| Cartilage/Synovium/Bursa | **All** | **14** | **13.7** | **9** | **8.8** | **5** | **4.9** |
| | Cartilage injury | 3 | 2.9 | 2 | 2.0 | 1 | 1.0 |
| | Synovitis/Capsulitis | 10 | 9.8 | 7 | 6.9 | 3 | 2.9 |
| | Bursitis | 1 | 1.0 | - | - | 1 | 1.0 |
| Ligament/Joint capsule | **All** | **20** | **19.6** | **15** | **14.7** | **5** | **4.9** |
| | Joint sprain (ligament tear/acute instability episode) | 20 | 19.6 | 15 | 14.7 | 5 | 4.9 |
| Superficial tissues/skin | **All** | **1** | **1.0** | **1** | **1.0** | **-** | **-** |
| | Laceration | 1 | 1.0 | 1 | 1.0 | - | - |
| Other | **All** | **10** | **9.8** | **8** | **7.8** | **2** | **2.0** |

Muscle/tendon tissue type injuries accounted for the majority of RRIs among consenting trail runners (All: 44.1%, n=45; Males: 27.5%, n=28; Females: 16.7%, n=17) followed by ligament/joint capsule (All: 19.6%, n=20; Males: 14.7%, n=15; Females: 4.9%, n=5). Tendinopathy (All: 27.5%, n=28; Males: 15.7%, n=16; Females: 11.8%, n=12), joint sprain (All: 19.6%, n=20; Males: 14.7%, n=15; Females: 4.9%, n=5), and muscle injury (All: 15.7%, n=16; Males: 10.8%, n=11; Females: 4.9%, n=5) were the most common pathology types affected by RRIs in the 12 months prior to the race.

The mean injury severity score for RRIs sustained during the 12 months prior to the race, was 31.6 (95% CI; 27.9-35.3) out of 100. The individual injury severity scores ranged from 0 to 80.

Univariate analysis (unadjusted) of potential risk factors associated with RRIs among consenting trail runners

The following variables were explored as associated RRI risk factors among consenting trail runners: age, sex, BMI, average weekly running distance and vertical gain, total running experience (years), total trail running experience (years), average number of any running sessions per week, and average number of trail running sessions per week.

In Table 5, the univariate analysis results (p-values) are depicted with the statistical significance set at $p<0.05$.

**Table 5: Univariate analysis of variables in relation to RRI among trail runners p-values**

| Variable | Effect size | p-value |
|---|---|---|
| Age* | 0.0264 | 0.9755 |
| Sex* | 0.0089 | 0.8768 |
| BMI[#] | 0.0636 | 0.2671 |
| Average weekly running distance* | 0.1174 | 0.3794 |
| Average weekly vertical gain* | 0.0424 | 0.9688 |

| | | | |
|---|---|---|---|
| Total running experience | Running* | 0.1067 | 0.1760 |
| | Trail running* | 0.0558 | 0.6221 |
| Average number of running sessions per week | Running sessions* | 0.0674 | 0.5001 |
| | Running sessions on trail* | 0.0671 | 0.5081 |

*: Pearson's Chi-squared test
#: Mann Whitney U test

From the nine variables included in the univariate analysis, not one variable showed a statistically significant association with RRIs in the past 12 months among consenting trail runners.

## DISCUSSION

This study is the first to investigate the epidemiology and clinical characteristics of RRIs among trail runners during the 12 months leading up to the 2019 SkyRun race. Our main findings include: 1) 28.2% of participants reported at least one injury during the 12 months showing a retrospective annual incidence of 49.5 RRIs per 1000 hours and point prevalence of 1.3%; 2) most injuries occurred in the lower limb (87.3%); 3) the most commonly injured body areas involved the knee (26.5%), ankle (21.6%), and foot (16.7%); 4) muscle/tendon (44.1%) were the most commonly reported tissue type injuries; 5) tendinopathy (27.5%), joint sprain (19.6%), and muscle injury (15.7%) were the most common pathology types reported; 6) the mean injury severity score was 31.6, and 7) none of the variables included in the univariate model showed an association with RRIs.

The majority of studies that investigated injury-related outcomes among trail runners focused on medical encounters during race participation.[9-13,30] Only two studies included training-related injury outcomes[15,16] where runners were exposed to different running surfaces and environmental conditions which provide challenges in comparing our results to current literature.

Among Dutch trail runners, 42.1% of participants reported an RRI during the past 12 months with 18.0% of participants reporting a current injury.[15] The current study results, based on a compulsory pre-race medical questionnaire prior to race participation, showed only 28.2% of runners reported an RRI in the past 12 months and a lower point prevalence of 1.3%. This may be due to under reporting of RRIs as race entrants may have feared being disqualified from race participation in the case of severe health problems.

Similar to conventional forms of running,[5,31] the lower limb (87.3%) was the most common anatomical region of injury among both male (95.5%) and female (72.2%) trail runners in our study. Hespanhol Junior et al. did not report on sex categories with regards to the clinical characteristics of injury, but among all participants they reported the lower leg (20.6%), followed by the knee (18.9%), and foot (14.9%) as the most common body regions of injury.[15] The knee (26.5%) and foot (16.7%) were also commonly reported among our study participants, but in contrast to Dutch trail runners[15], the ankle (21.6%) was also a common site for RRIs among our sample of consenting trail runners. The ankle presented as the most common body area injured specifically among female race entrants (22.2%) with the knee the most common body area injured among males (30.3%) in our study. A possible explanation for the difference in findings between the Dutch study and our study may be that the Dutch trail runners commonly trained on paved surfaces as they had limited access to trails.[15] In our study participants trained mostly on off-road terrains (76.5%). A cross-sectional study investigating injury among Greek trail runners participating in mountainous regions did not report on ankle injuries.[16] The authors reasoned that the participants could not accurately report on ankle injuries retrospectively due to the high occurrence thereof.[16]

The muscle/tendon was the most common injured tissue type reported among all consenting trail runners (44.1%) and among both male (27.5%) and female (16.7%) categories in our study. Similarly, tendinopathies were the most common pathology type reported among all trail

runners (27.5%) and both male (15.7%) and female (11.8%) categories in our study. This is in line with the results among Dutch trail runners who reported muscle (27.7%) and tendon (23.6%) as the most common injured tissue.[15] Running involves repetitive lower limb movements where soft tissue plays an important role in the absorption of ground reaction forces.[32] In addition, trail running involves high eccentric muscle work especially during downhill running resulting in increased muscle damage.[33] The combination of repetitive ground force absorption and larger eccentric demand could be the reason for the high frequency of muscle and tendon injuries reported among trail runners. Of interest is that joint sprains (19.6%) were the second most common pathology type reported. Increased muscle activity is required to maintain balance on unstable surfaces compared to stable surfaces.[34] The majority of our sample (76.5%) reported training on off-road surfaces which could explain the higher frequency of joint sprains reported.

Similar to Hespanhol Junior et al.[15] we used the OSTRC-H score to report on injury severity.[35] Among our sample of consenting trail runners a mean severity score of 31.6 was reported which is in agreement with the mean severity score (35.0) among Dutch trail runners.[15] The resemblance of the severity score is unexpected considering the different study designs used and environmental conditions participants were exposed to during trail running in the diverse geographical regions.

None of the variables included in the univariate risk factor analysis showed a statistically significant association with sustaining an RRI in the 12 months prior to the 2019 SkyRun race. This finding should be interpreted in the context of the complexity of sports injuries.[36] A sports injury does not occur due to the presence of isolated factors, but is more likely due to complex interactions between multiple factors otherwise known as a "web of determinants".[36] This study only investigated a limited number of potential injury risk factors as determined by our sample size and available information. Future studies using larger sample sizes should aim to include

further intrinsic risk variables and perform a multivariate analysis to determine injury risk factors.

Strengths and limitations

One of the strengths of this study was that 74.0% of all the 2019 SkyRun race entrants consented to inclusion as study participants and were a confirmed representative sample of the total population. This study initiated a very important gap in trail running literature regarding the epidemiology and characteristics of injury during training for trail run races. The current results need to be interpreted in the context of the limitations of our cross-sectional study that used self-reported injury data based on injuries that occurred during the previous 12 months. Future studies should focus on prospective cohort study designs with regular follow-up to limit recall bias. The low point prevalence of injury could have been affected by runners fearing disqualification during the pre-race medical screening process. We acknowledge that the data on injury pathology type could not be substantiated as participants might not have understood the terminology used in the questionnaire. We did not find any associated injury risk factors in this study, but this may be due to our small sample size. We studied a specific population of trail runners training towards a race in a mountainous region at high altitude. Therefore, our results cannot be generalised to trail runners training towards races in different natural environments (forests, desert, etc.).

## CONCLUSION

Approximately 1 in every 4 SkyRun trail runners reported at least one injury in the past 12 months. Trail runners training for the 2019 SkyRun reported RRIs that mostly affected the lower limb specifically the knee, ankle and foot. This emphasises the need to establish injury risk factors to assist in the design of specific injury prevention strategies, as the recurrence of injury during a trail run race may have dire consequences.

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