Development of a trail running injury screening instrument: a multiple methods approach

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HIGHLIGHTS

- We developed a clinical decision aid for injury risk management in trail running.
- Multiple injury risk factors may contribute to injury in trail running.
- Ten domains of injury risk were identified through human judgement modelling.

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.[49] Trail runners are often exposed to significant elevation changes and variable running surfaces in natural environments, such as mountains, forests and deserts.[18] Running has numerous health benefits[24], but trail running also has a high incidence of up to 61.2 injuries per 1000 hours reported.[57]

During training or racing, a trail runner can be exposed to gradual onset injury like tendinopathies[15, 22] or sudden onset injury like ankle sprains.[12, 56] Trail running is semi- to fully self-sufficient, and runners are sometimes required to use running packs in races to carry limited nutritional supplies and safety equipment,[44] while often traversing remote natural environments. In remote regions, medical support is challenging in terms of finding and evacuating injured runners.[16] 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.[45] There is a clear administrative need for improved medical coverage in trail running, but from a logistical perspective it is challenging and not always feasible in remote regions. Therefore, it is important to identify runners at an increased risk for injury before training or race participation in remote environments. To optimise holistic injury risk management, we also need to consider training-related running exposure among trail runners. Trail runners perform regular training in urban areas on asphalt surfaces in preparation for larger races in

remote regions.[15, 56] To allow for consistent training and access to running-related health benefits, clinicians, i.e. healthcare professionals working in clinical practice such as medical doctors, physical therapists, biokineticists, and athletic trainers, 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[57] 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.[48] 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 more recently gaining in popularity and being a smaller sport,[49] few clinicians get regular exposure to injury risk management in trail running. In the presence of limited research evidence, we can utilise the knowledge of current experts in the field to assist clinical decision-making regarding injury risk management, in the context of EBM.[48]

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**.

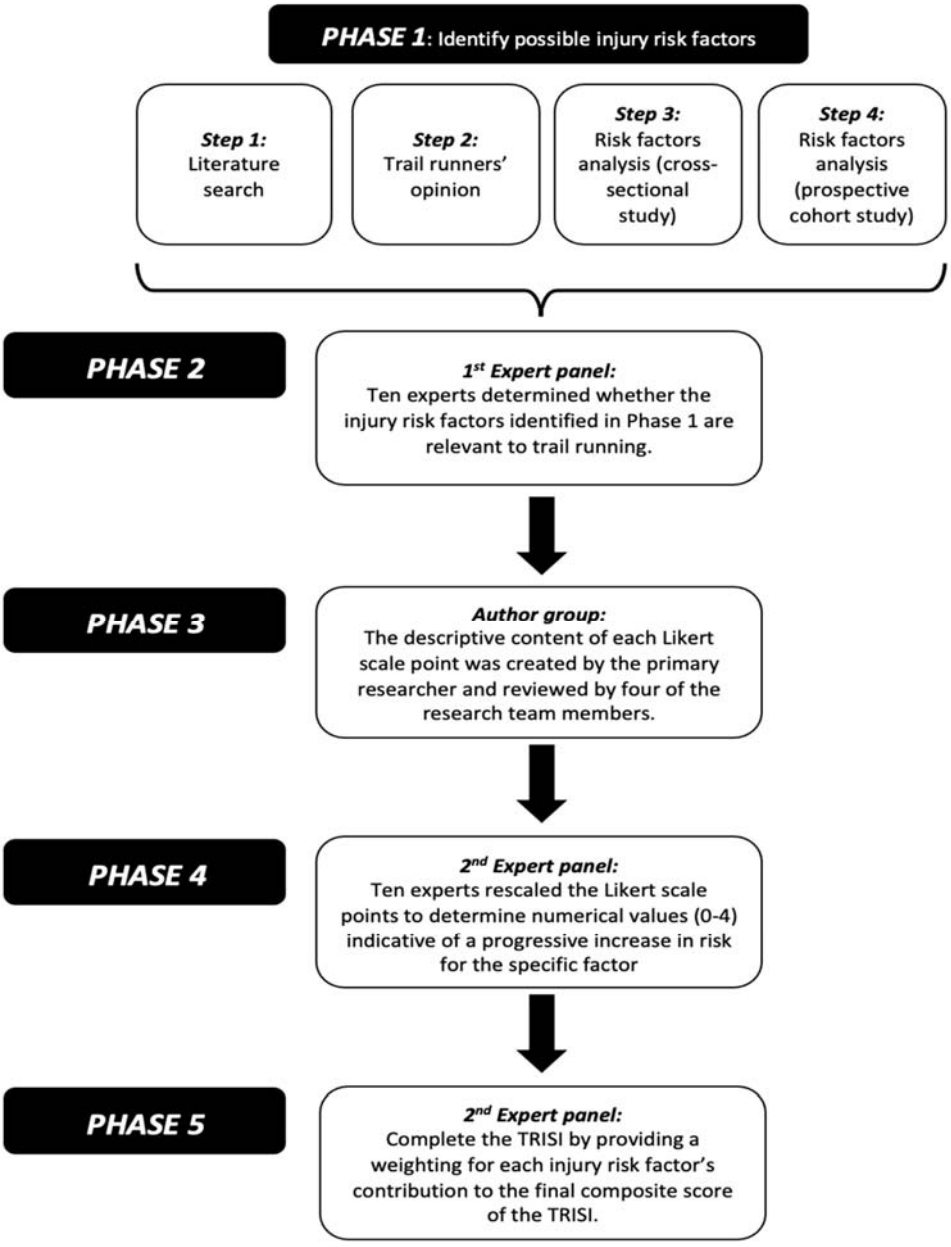


FIGURE 1. The five phases of the TRISI development

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[49]). 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 (xxxx) 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.[56] 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.[57] Therefore, we analysed cross-sectional data collected at the Two Oceans trail runs (10km and 22km) over four years[58] to identify risk factors associated with gradual onset running-related injuries. Using the original data, we could investigate factors related to runner demographics (sex, age, and race distance entered), training/racing history (race vs training speed ratio, average weekly running frequency, distance, and training speed), history of chronic disease, and history of allergies. We added all the statistically significant ($p<0.05$) injury risk factors from the univariate analysis 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.[57] Therefore, we investigated injury risk factors among trail runners by conducting a prospective cohort study over six months, following runners biweekly.[56] We investigated factors in the categories of runner demographics (age, sex, and BMI), running experience (years of all running and trail running), training characteristics (running surface exposure, average frequency or running, running distance, total ascent, total descent, and types of cross-training), previous injury history, current injury, and history of chronic disease. 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**). The authors individually identified panellists. Subsequently, the author group collectively agreed upon inclusion of each panellist. Each panellist received the provisional Phase 1 injury risk factor list via email for independent review. The panellists were not allowed to discuss their decisions with one another. 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.

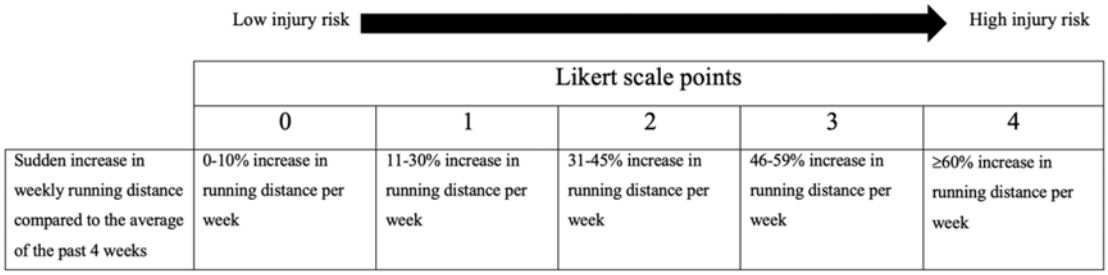
TABLE 2, Phase 2, 4, and 5 expert panellists (n=20)

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 (xxxx) and reviewed by four of the authors (xxxx, xxxx, xxxx, and xxxx). 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
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

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.[2] 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[2], 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,[30] all running,[3, 5-11, 13, 14, 17, 20, 21, 25-29, 31, 32, 34-43, 46, 47, 50, 52-54, 59-61] and runners' opinion on factors associated with a higher risk for injury[23, 51] (**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 [30]	-	X [51]	80*
	Competitive training	-	-	-	-	-	X [51]	80*
	Training with more advanced running partners	-	-	-	-	-	X [51]	80*
	Regular participation in running races	-	-	-	-	-	X [51]	63
	Not performing regular stretching	-	-	X	-	-	X [51]	60
	Not performing a warm-up routine before running	-	-	X	-	-	X [51]	78
	Lack of interval training	-	-	-	-	X [53]	-	50
	Regular alternating between high and low distance runs	-	-	-	-	X [41]	-	20
	Higher weekly running distance	X	X	-	-	-	-	75
	Multiple training sessions per day	-	-	-	X [30]	-	-	70
	Higher number of running sessions per week	X	-	-	-	-	-	90*
	Lack of recovery	-	-	X	-	-	X [23]	100*
	High total weekly running distance	X	-	-	-	-	-	75
	Sudden increase in weekly running distance	-	-	X	-	X [38 54 14]	X [23]	100*
	Irregular training	-	-	X	-	-	X [51]	80*
	Higher running intensity	-	-	-	-	X [21]	-	80*
	More running experience	-	X	-	X [30]	X [50]	-	0
	Lack of running experience (<5 years)	-	-	-	-	X [53 20 6 59]	X [51]	60
	Running on asphalt more often than on trails	-	-	-	X [30]	X [39]	-	67
	Faster running pace	-	-	X	-	-	X [51]	40
	Slower running pace	X	-	-	-	-	-	10
	Uphill running (elevation gain)	-	-	X	-	-	X [51]	33
	Downhill running (elevation loss)	-	-	X	-	-	X [51]	56
	Running at higher altitudes	X	-	-	-	-	-	14
	Lack of muscle strengthening	-	-	X	-	-	X [51 23]	78
	Regular running on irregular terrain.	-	-	X	-	X [41]	X [51]	20
	Running while listening to music	-	-	X	-	-	X [51]	33
	Previous sports participation without axial loading	-	-	-	-	X [7]	-	40
Equipment	Lack of cushioning in running shoes	-	-	-	-	-	X [51]	70

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	
	Buying running shoes based on a running analysis and not primarily based on a good fit	-	-	-	-	X [61]	-	100*
	Low heel-to-toe drop in running shoes	-	-	-	-	-	X [51]	40
	Evidence that the shoes are worn down	-	-	-	-	-	X [51]	90*
	Running with only one pair of shoes	-	-	-	-	X [39 29]	-	44
	Rapid transition from cushioned shoes to using minimalist running shoes	-	-	-	-	X [46]	-	100*
	Use of orthotics in running shoes	-	-	-	-	X [17]	-	44
Demographic profile	Occupations that involve physical labour	-	-	-	X [30]	-	-	30
	High body mass index (BMI)[a]	-	-	-	-	X [53 20 59 39 7 37]	X [51]	80*
	Low BMI[a]	-	-	-	-	X [50]	-	60
	Male	-	-	-	-	X [59 47]	-	0
	Female	-	-	-	-	X [32]	-	13
	Older age	-	-	-	-	X [20 37]	X [51]	56
	Younger age	-	-	-	-	X [6]	-	33
Injury history	History of previous injury (musculoskeletal complaint) not related to sports	-	-	-	-	X [20 37]	-	100*
	History of previous running-related injury (past 12 months)	X	-	-	-	X [54 50 59 7 17 52 10 3 25]	X [51]	100*
	Current injury	X	-	-	-	-	-	100*
Behavioural factors	Ignoring pain while running	-	-	X	-	-	X [51 23]	90*
	Lack of concentration during running	-	-	X	-	-	X [51]	100*
	Runners motivated by external pressure	-	-	-	-	X [8]	-	78
	Non-competitive runners	-	-	-	-	X [37]	-	0
	Poor sleep quality	-	-	X	-	X [14]	-	100*
Psychological factors	Periods of psychological stress	-	-	-	-	-	X [51 23]	100*
	Running while mentally fatigued	-	-	-	-	X [9]	-	100*
Nutrition	Runner's perception of having an unbalanced diet	-	-	-	-	-	X [51]	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*

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	
	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 [42]	-	100*
	Oligo/amenorrhea	-	-	-	-	X [41]	-	100*
Biomechanical variables	Higher peak braking force	-	-	-	-	X [36 26]	-	88*
	Lower step rate during running (≤164 steps per min)	-	-	-	-	X [28]	-	60
	Leg length discrepancy > 1.5cm	-	-	-	-	X [40]	-	78
	Poor hip abductor muscle strength	-	-	-	-	X [27 34]	-	89*
	Poor knee extensor muscle strength	-	-	-	-	X [27 60]	-	100*
	Poor knee flexor muscle strength	-	-	-	-	X [27]	-	100*
	Increased peak external knee abduction moment (knee varus)	-	-	-	-	X [13]	-	67
	Rearfoot strike during running	-	-	-	-	X [35 11]	-	22
	High peak rearfoot eversion	-	-	-	-	X [34]	-	50
	Increased stride length during running	-	-	-	-	X [35]	-	63
	Narrow step width during running (cross-over running style)	-	-	-	-	X [31]	-	38
	Highly supinated foot	-	-	-	-	X [39]	-	63
	Highly pronated foot	-	-	-	-	X [39]	-	63
	Greater pressure on the medial side of the shoe during running	-	-	-	-	X [34 5]	-	29
	Narrower bimalleolar width ≤ 70.5 mm	-	-	-	-	X [43]	-	80*
	Earlier peak pressure under the fifth metatarsal, indicative of earlier supination	-	-	-	-	X [43]	-	57

*: ≥80% level of agreement

[a] body mass index

[b] analgesic/anti-inflammatory medication

3.3. Phase 3:

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.	
	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.	**5.41**
	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.	
	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	**5.11**
	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	
	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	**4.79**
	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.[33] (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.[62] (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".[63]		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".[63]	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.[1] (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:

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:

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.[4] 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.[19] 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.[19] 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.[55]

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. To ensure trail runner's personal information is protected, the TRISI will adhere to the guidelines as stipulated by the Protection of Personal Information Act (POPI) and the General Data Protection Regulation (GDPR). After a secure online profile is created for a runner, the clinician can continue with the injury screening process. During the screening process, the clinician will be guided on how to score each risk factor, using the information obtained from 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.

4.2. 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 (estimated one repetition maximum) 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.

4.3. 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.[4] 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.

4.4. 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.

5. 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.

6. 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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I affirm that I have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript.

Author contributorship

Conception and design of the study (CTV, CJvR), literature search (CTV), data collection (CTV), data interpretation (CTV, CJvR, WvM, EV), manuscript write-up (CTV), manuscript editing (CTV, CJvR, WvM, EV, EK), Statistical analysis of data (TC, CTV).

Conflicts of interest

None declared.

Ethics approval

The study was approved by the Research Ethics Committee of the Faculty of Health Sciences at the University of Pretoria (REC no: 469/2018). All participants gave informed consent.

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