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Original research

Risk factors associated with medical encounters in ultramarathon race starters – Data from 103,131 race starters over 90 km: SAFER XLI

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ABSTRACT

Objectives: To identify the risk factors associated with all medical encounters (MEs) and serious/life-threatening MEs (SLMEs) during the Comrades Marathon.
Design: Prospective cohort study, with cross-sectional analyses.
Methods: During the 2014–2019 Comrades Marathon, all MEs (including SLMEs) were recorded in 103,131 starters. For both all MEs and SLMEs, the following risk factors were explored: sex, age, route ("up" vs. "down" race), previous Comrades experience (yes/no), wet-blub globe temperature (WBGT) and race pace. Incidence (per 1000 starters; 95%CI), and the incidence ratio (IR; 95%CI) are presented.
Results: For all MEs, being female was a significant risk factor (females vs. males IR = 1.47, $p < 0.0001$), and age was only marginally significant ($p = 0.0167$). Therefore factors for all MEs were adjusted for sex. Other factors significantly associated with all MEs were: higher WBGT (highest WBGT compared to lowest, IR = 1.33, $p = 0.0003$), race pace (highest risk for those who finish either among the first quarter [IR = 1.49] or last quarter [IR = 1.46] compared to middle pace; $p < 0.0001$) and the route ("down" vs. "up": IR = 1.11; $p = 0.0181$). Factors associated with higher risk for SLMEs were: females (IR = 1.9; $p = 0.0003$), "down" vs. "up" route (IR = 1.37; $p = 0.0306$) and race pace (slower and faster runners vs. mid (6.4–7.1 min/km) race pace category (IR > 2.1, $p < 0.0001$)).
Conclusions: Intrinsic (female, faster and slower race pace) and extrinsic (higher WBGT and the "down" route) are novel risk factors associated with all MEs at this event. These can be considered by the race organizers and the medical team to develop and implement prevention strategies.

1. Introduction

It is well-documented that prolonged endurance running events such as marathons, and particularly ultramarathons, have a high incidence of medical encounters (MEs) during and immediately after the event. The methodology of data collection reported in different studies does make comparisons of the incidence of MEs at running events difficult. This is mainly because the definition of an ME (including less severe) varies, and the denominator (entrants/starters/finishers) is not consistent. In studies where the same or a similar definition of ME is used, the incidence of all MEs during different race distances is reported as: 6.2 per 1000 (10 km event),[1] 5.1 per 1000 starters (21.1 km event) and 13 per 1000 starters in marathons.[2,3] The incidence of serious/life-threatening medical encounters (SLMEs) and deaths is between 3.19 and 3.68 per 100,000 runners, again dependent on the race distance.[4] Even with the methodological discrepancies, the trend is clear that the incidence of MEs increases significantly with race distance (half marathons vs. marathons, ultramarathons).[4,5]

While knowing the incidence of MEs assists medical support staff and race organizers prepare, the risk factors associated with these MEs are the next step that is needed to develop and implement programs to prevent MEs.[6] Risk factors for all MEs and specific MEs have been investigated in various distance running events. In the Two Oceans Marathons, for the 21.1 km older females were at a higher risk,[7] and for the 56 km the fastest and slowest runners, as well as the inexperienced runners were at highest risk.[8] In the Shanghai International Marathon, weekly running distance and wearing "used shoes" were risk factors associated with MEs (race experience was not associated in this study).[9]

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In a multi-day ultramarathon, older age and males were found to be at lower risk for MEs.[10] For specific MEs by organ system or specific diagnosis, males have been associated with a higher risk of sudden cardiac arrest (compared with females),[11] and for exertional heat stroke (EHS), there is a significant association with the weather conditions.[12] Factors such as demographics, environmental conditions and prior race experience should thus be taken into account when attempting to explain the ME rates in an event.

The Comrades Marathon is a 90 km road running event, widely accepted as the largest road ultramarathon (by participation numbers) in the world, with 25,000 entrants and an average of 16,000 starters annually. Using the cohort of 103,131 starters over six years (2014–2019) in the Comrades Marathon, we have reported a very high incidence of illness-related MEs at 19.1 (18.3–20.0) per 1000 starters, and SLMEs at 1.8 (1.6–2.1) per 1000 starters.[13] The aim of this study was to explore selected risk factors that may be associated with all MEs and SLMEs during this mass community-based participation endurance running event (Comrades Marathon).

2. Methods

2.1. Study design

This is a cross-sectional analysis of retrospective data collected over 6 years (2014–2019). Ethical clearance was obtained from the Research Ethics Committee of the University of Pretoria (REC 431/2015).

2.2. Participants and demographics

This study forms part of a series of studies known as the SAFER (**S**trategies to reduce **A**dverse medical events **F**or the **E**xercise**R**) studies.[14] This study is a component of the retrospective analysis of data collected on all race starters during the Comrades Marathon from 2014 to 2019. Data on registrants, starters and finishers were obtained, with permission, from the race organizers. These data, which include age, sex, and finish times are in the public domain and are obtainable from the race website. This ultramarathon is an annual 90 km running event attracting approximately 16,000 starters each year. It is held between the cities of Durban to Pietermaritzburg on the east coast of South Africa. The route of the race between the two cities alternates each year and there is a 648 m elevation difference between the two cities. The alternating routes for the race are known as the "up" (Durban to Pietermaritzburg) or the "down" (Pietermaritzburg to Durban) run. All participants are required to qualify for the Comrades Marathon with the minimum qualifying distance being a 42.2 km event in less than 4:49:59 h within 8 months prior to the event (qualification times do change). Participants are seeded into starting categories to stagger the start (total stagger time is maximum 10 min) based on qualifying times, as well as having multiple cutoff times throughout the race with participants being removed from the course. The cutoff times at specific race distances are based on information from timing mats, and a runner who does not meet the cutoff time at a specific race distance is then deemed a "did-not-finish". The Comrades race organizers periodically change the cutoff times for the specific distances, particularly for up vs. down races. A minimum age of 20 years at time of event (there is no maximum age) is implemented. The Comrades Marathon is usually held in early June (autumn/winter) beginning at 5:30, and the cutoff finish time is 17:30. During this study period a total of 133,641 runners entered, and 103,131 runners started the races (race starters = 77.2 % of registrations).

2.3. Medical encounter data collection

We have previously reported the details of the medical encounter (ME) data collection,[13] which were in accordance with the 2019 international consensus statement on data collection in mass community-based endurance sport events.[15] The diagnoses of MEs were made by experienced physicians, using clinical criteria, and point-of-care testing for certain MEs when necessary. The attending physicians on each race day during the 6-year study period recorded accurate and detailed clinical information of each medical encounter in a standardized format that included the system affected as well as the specific final diagnosis. Only MEs defined as moderate and/or serious/life-threatening severity (or death) were recorded in this study.[15] MEs were classified into main organ system (and specific diagnosis),[15] and further severity including serious/life-threatening and event-related deaths. All SLMEs were reviewed and classified by another medical doctor (MS) as moderate or serious life-threatening, according to the criteria as defined in the 2019 international consensus of reporting medical encounters.[15] For this study, the risk factors for all MEs (including serious/life-threatening) and the risk factors for SLMEs were investigated. Using data from the entry, starter and finisher database, risk factors that could be investigated included: sex, age, wet-bulb globe temperature (WBGT), route (up vs. down run), previous Comrades Marathon experience (yes/no) and race pace (calculated using finish time, min/km).

2.4. Environmental conditions on race days for each year

Hourly environmental data were collected between 5:00 and 18:00 on race day, from automated weather stations of the South African Weather Services along the race route (Supplementary Fig. 1). The average WBGT[16] index was taken over the 4 weather stations (Supplementary Table 1). The cumulative WBGT score was calculated by averaging the WBGT indices over 4 weather stations from 2014 to 2019 on race day from 5 am to 6 pm. Thereafter, an average cumulative exposure measure was derived for each individual athlete. This was done by weighting the total hours that each athlete took to complete the race by the hourly modeled indices of WBGT. A cumulative exposure measure was calculated by using the average total run time for each athlete in order to individualize this measure for the athlete (see an example beneath Supplementary Table 1).

2.5. Patient and public involvement (PPI)

We did not directly include PPI in this study, but the race organizer and medical director were consulted, and the medical director was directly involved with data collection and interpretation.

2.6. EDI statement

The author team consists of three females and three males, includes two medical doctors, and all authors are from South Africa. The team was a mix of young and established researchers.

2.7. Outcome measures

The primary outcome variable was all MEs, and the secondary outcome variable was all SLMEs. The risk factors investigated for both all MEs and SLMEs were sex, age, WBGT, route (up/down race), previous Comrades experience (yes/no) and race pace (min/km).

2.8. Statistical analysis of data

All race starters' data were analyzed using *SAS statistical software (version 9.4, Cary NC)*.

The dependent variables in the model were binary variables, medical encounters (MEs) and serious/life-threatening encounters (SLMEs). Descriptive statistics were used to summarize the demographic characteristics of the study population of race starters by sex and age categories. The Poisson distribution with an associated log link in PROC GENMOD was used for analysis. A repeated statement was included to account for the exchangeable correlation structure as one runner

Table 1
Demographics of race starters and finishers (by sex, age categories).

			All years	
			n	%
Total starters	All		103,131	100
	Males	All	81,580	79.1
		≤30 yrs	6828	8.4
		31–40 yrs	29,884	36.6
		41–50 yrs	29,508	36.2
		>50 yrs	15,360	18.8
	Females	All	21,551	20.9
		≤30 yrs	2204	10.2
		31–40 yrs	8637	40.1
		41–50 yrs	7772	36.1
		>50 yrs	2938	13.6
Total finishers	All		86,284	100
	Males	All	69,156	80.1
		≤30 yrs	6000	8.7
		31–40 yrs	26,460	38.3
		41–50 yrs	25,123	36.3
		>50 yrs	11,573	16.7
	Females	All	17,128	19.9
		≤30 yrs	1796	10.5
		31–40 yrs	7136	41.7
		41–50 yrs	6200	36.2
		>50 yrs	1996	11.7

could enter for many races over the 6-year period. P-values for Type 3 Generalized Estimating Equation-analysis were reported. For all MEs, incidence (per 1000 starters and 95 % confidence interval [CIs]), adjusted for sex was reported for all potential risk factors (RFs), as well as the incidence ratios (IR; 95%CI). For SLMEs incidence (unadjusted) (per 1000 starters and 95 % confidence interval [CIs]) and IRs were reported for all potential risk factors (RFs). Potential RFs included sex, age, WBGT, route (up vs. down), previous Comrades Marathon experience (yes or no), and race pace (min/km). All variables were entered into the univariate models as categorical variables. There was no data available for the variable "previous experience" for 2014, and therefore 2014 was not included in that analysis.

The frequency and percentage of MEs and SLMEs were reported, as well as the incidence (per 1000 race starters). A p-value between 0.01 and 0.05 was considered marginally statistically significant. A p-value <0.01 was considered statistically significant.

3. Results

3.1. Participant demographics

Table 1 shows a summary of the demographics of race starters and finishers over the six years (for further details for each individual year see Supplementary Table 2). Over the six years, 103,131 participants started the race, and 86,284 finished (16.3 % did-not-finish rate). In total, 83.7 % of the starters finished the race. Females >50 years were the group with the highest did-not-finish rate (68 %).

3.2. Risk factors associated with all MEs

3.2.1. Demographics, route, and previous race participation

The risk factors investigated for all MEs are presented in Table 2. Overall there were 2025 MEs, of which 54 were injuries and 1971 were illnesses, with the overall incidence for MEs being 19.9 (95%CI: 19.0–20.9) per 1000 starters (see Supplementary Table 3 for MEs by year). The ME incidence for 2014 (23.8; 95%CI: 21.4–26.4) was significantly higher compared to the average ME of 2015–2019 (19.2; 95%CI: 18.3–20.3; p = 0.0002). Female sex was a significant factor associated with increased risk of MEs (1.5 (95%CI: 1.3–1.6) times higher risk, p < 0.0001) and younger runners had a slightly higher risk (marginally significant). Therefore, all further estimates for risk factors were adjusted

Table 2
The incidence (per 1000 starters: 95%CI) of any medical encounter (ME) during the Comrades Marathon for each risk factor (n = 103,131).

Variable	Category	Medical encounters (n)	Incidence (per 1000 starters)	95%CI	IR (95%CI)	p-Value
Overall		2025	19.9	19.0–20.9		
Sex	Male	1459	18.1	17.1–19.1		
	Female	566	26.6	24.3–29.0	1.47 (1.33–1.63)	<0.0001
Age category (years)	≤30	226	25.0	21.8–28.6	1.27 (1.07–1.52)	0.0167
	31–40	746	19.7	18.2–21.2	1.00 (0.88–1.15)	
	41–50	701	18.9	17.5–20.5	0.97 (0.84–1.12)	
	>50	352	19.6	17.5–21.9	ref	
Variables adjusted for sex*						
Route (up/down race)	Up	981	20.8	19.5–22.2		0.0181
	Down	1044	23.0	21.5–24.6	1.11 (1.02–1.20)	
Previous participation in the Comrades (experience)	Yes	1303	20.5	19.2–21.9		
	No	379	22.9	20.8–25.4	1.12 (1.00–1.25)	0.0628
Finish status	Finishers	1682	21.9	20.7–23.2		
	Non-finishers	343	21.7	19.5–24.2	0.99 (0.88–1.11)	0.8516

Overall incidence of medical encounters, adjusted for sex: 21.9 (20.8–23.1) per 1000 starters.
Experience: n = 88,735 (2014 excluded as no data on this), 1682 ME total for experience.
* Adjusted for sex but not age (due to marginal significance of p > 0.01).

Table 3
The incidence (per 1000 finishers: 95%CI) of any medical encounter (ME) during the Comrades Marathon for WBGT and race pace for finishers (adjusted for sex) (n = 86,284).

Variable	Category	Medical encounters (n)	Incidence (per 1000 finishers)	95%CI	IR (95%CI)	p-Value
Environmental conditions (WBGT)	11.3–14.4	353	18.6	16.7–20.7	ref	0.0003
	14.4–15.9	430	22.3	20.2–24.5	1.20 (1.05–1.37)	
	15.9–17.8	418	21.8	19.8–24.1	1.18 (1.03–1.35)	
	17.8–20.0	478	24.7	22.6–27.1	1.33 (1.17–1.52)	
Race pace (min/km)	3.5–6.4	492	26.2	23.5–29.1	1.49 (1.29–1.73)	<0.0001
	6.4–7.1	336	17.5	15.6–19.6	ref	
	7.1–7.7	360	18.9	17.0–20.9	1.08 (0.93–1,25)	
	7.7–8.5	492	25.6	23.4–28.0	1.46 (1.27–1.68)	

WBGT: Wet-bulb globe temperature for the race day; missing n = 322.
Race pace: missing n = 243.

Table 4
The incidence (per 1000 starters: 95%CI) of serious/life-threatening medical encounters (SLME) for each risk factor during the Comrades Marathon (unadjusted) (n = 103,131).

Variable	Category	Serious/life-threatening MEs (n)	Incidence (per 1000 starters)	95%CI	IR (95%CI)	p-Value
Overall		189	1.8	1.6–2.1		
Sex	Male	125	1.5	1.3–1.9		
	Female	64	3.0	2.3–3.8	1.94 (1.44–2.62)	0.0003
Age category (years)	≤30	26	2.9	2.0–4.2	1.59 (0.95–2.66)	
	31–40	76	2.0	1.6–2.5	1.09 (0.73–1.65)	
	41–50	54	1.4	1.1–1.9	0.80 (0.52–1.24)	
	>50	33	1.8	1.3–2.5	ref	0.0612
Route (up/down race)	Up	107	1.6	1.3–1.9		
	Down	82	2.1	1.8–2.6	1.37 (1.03–1.82)	0.0306
Previous participation in the Comrades (experience)	Yes	119	1.8	1.4–2.0	1.42 (1.00–2.02)	0.0727
	No	43	2.4	1.8–3.2		

Experience: n = 88,735 (2014 excluded as no data on this), SLME n = 162.

for sex. Another risk factor significantly associated with all MEs was the route, where the "down" race was associated with a marginally higher risk of MEs compared to the "up" race (IR = 1.1 (95%CI: 1.0–1.2); p = 0.0181).

3.2.2. Environmental conditions (WBGT) and race pace

The incidence of MEs by WBGT and race pace as risk factors for all MEs are shown in Table 3. A higher WBGT was significantly associated with increased risk of MEs ($p = 0.0003$), with the highest ME risk in the highest compared to the lowest WBGT category (IR = 1.3; 95%CI: 1.2–1.5). For race pace, the risk of MEs was significantly higher in the fastest and slowest categories compared with the middle categories (IR = 1.5; 95%CI: 1.3–1.7; $p < 0.0001$).

3.3. Risk factors associated with all SLMEs

Majority of the SLMEs were attributed to dehydration (31 %), and the cardiovascular system accounted for 26 %.[13] The incidence of SLMEs for each risk factor is in Table 4. Almost 1 out of every 500 race starters had presented with a SLME. Being female vs. male was a significant risk factor associated with SLMEs (IR = 1.9; 95%CI: 1.4–2.6, $p = 0.0003$). The incidence for WBGT and race pace risk factors for SLMEs are shown in Table 5. For race pace, the risk of SLMEs was significantly higher in the fastest (IR = 2.5; 95%CI: 1.4–4.4) and slowest categories (IR = 3.9; 95%CI: 2.3–6.8) compared with the middle categories ($p < 0.0001$).

4. Discussion

To our knowledge, this is the largest study to identify risk factors for all medical encounters and serious/life-threatening medical encounters during an ultra-marathon road running race. The main findings of this study were that for both all MEs and SLMEs during the 90 km Comrades Marathon, females and race pace (slow and fast) were significant risk factors. Additional risk factors associated with all MEs were, a higher WBGT and the route ("down" run).

Our first finding is that female 90 km race starters are at a higher risk for all MEs (IR = 1.5) and SLMEs (IR = 1.9). Female sex has been identified as a risk factor for MEs at some distance running events, including in a 21.1 km half-marathon event.[7] In that 21.1 km event, females had a 1.8× higher incidence of all MEs,[7] which is similar to data from the Comrades ultramarathon. However, in a 56 km there were no significant differences in the incidence of MEs among male and female starters.[8] In a group of ultra-trail runners, females had a higher incidence of illness-related MEs during the event,[10] while in other endurance events females are at a higher risk for a specific ME related to exercise associated hyponatreamia.[17] Females have also been shown to be at higher risk for exercise-associated postural hypotension (EAPH) in half-marathons.[18] Therefore in our study, it could be that the increased risk is due to MEs in specific organ systems (or specific diagnoses). We have reported that in our cohort at the Comrades Marathon there is a high incidence of EAPH (1.0 per 1000 starters) and fluid electrolyte disorders (8.8 per 1000 starters),[13] and therefore these could contribute to the increased risk for all MEs in females. Understanding the risk factors for specific organ systems/diagnoses by sex could assist in targeted interventions for this race and other similar events. However, if females are at a higher risk for MEs in all organ systems, then larger scale interventions can be implemented.

Our second finding is that younger age (≤30 years) is a risk factor for all MEs (marginal significance at $p = 0.0167$, IR = 1.3). This finding is in contrast to other studies in distance runners where older age was a risk factor associated with all MEs in a shorter race (21.1 km). Older age was also a risk factor for a specific ME such as exercise-associated muscle cramping in a 56 km ultra-marathon race.[7,8] Therefore younger age (≤30 years) as a risk factor for all MEs in the 90 km Comrades ultramarathon is novel. The reasons for this are not clear but we hypothesize that this may be related to the long distance (90 km) of the event and that younger runners may not have enough ultra-distance running experience (years of running). Peak performance in male and female ultramarathon runners is generally achieved between the age of 35 and 45 years for[19] and we suggest that for the 90 km Comrades Marathon the peak performance age could even be older. The relationship

Table 5
The incidence (per 1000 finishers: 95%CI) of serious/life-threatening medical encounters (SLMEs) during the Comrades Marathon for WBGT and race pace for finishers (unadjusted) (n = 86,284).

Variable	Category	Medical encounters (n)	Incidence (per 1000 finishers)	95%CI	IR (95%CI)	p-Value
Environmental conditions (WBGT)	11.3–14.4	45	2.1	1.6–2.8	1.80 (1.10–2.93)	0.0481
	14.4–15.9	43	2.0	1.5–2.7	1.72 (1.05–2.81)	
	15.9–17.8	25	1.2	0.8–1.7	ref	
	17.8–20.0	39	1.8	1.3–2.5	1.56 (0.94–2.57)	
Race pace (min/km)	3.5–6.4	40	1.8	1.3–2.5	2.48 (1.39–4.44)	<0.0001
	6.4–7.1	16	0.7	0.4–1.2	ref	
	7.1–7.7	34	1.6	1.1–2.2	2.13 (1.18–3.85)	
	7.7–8.5	62	2.9	2.3–3.7	3.92 (2.26–6.77)	

WBGT: 81 missing wet-bulb globe temperature for the race day, SLME n = 152 for WBGT.

between years of running and risk of MEs in this ultramarathon race requires further investigation.

A third main finding is that race pace is a risk factor associated with both all MEs and SLMEs. We show that both faster and slower runners have an increased risk for MEs and SLMEs. Previous studies during a 56 km race have shown slower running pace to be associated with increased risk of all MEs, and for specific causes of MEs, such as EAPH.[8] The precise explanation of these observations is not clear but we can speculate that for slower race pace runners, this may be related to several factors including poor race preparation, and a history of possible underlying medical conditions or injuries, and the larger "volume" of running compared to faster times. The reason/s that fastest runners have an increased risk of all MEs is novel and needs further investigation. Faster runners generally run at very high relative intensity and, when running at this high intensity for 90 km, this may place them at risk of developing MEs in a variety of organ systems.

A further main finding in our study was that route direction was a unique risk factor associated with MEs. We show that for all MEs the "down" run was associated with an increased ME risk compared to the "up" run. The "down" run involves prolonged downhill running, which has different biomechanical and physiological requirements,[20] and is associated with increased risk of muscle damage.[21] A combination of eccentric muscle damage and poor adaptation or inadequate preparation for downhill running may explain the increased risk of MEs during the "down" run, but this requires further investigation. It must be noted that there were only three years of "down" runs and therefore other factors should also be investigated that might confound the "down" run variable.

Finally, we show that a high WBGT was a significant risk factor associated with all MEs, however not for SLMEs. WBGT has been well documented as a factor influencing the incidence of MEs during endurance running events. In a study on 10 km road-running events there was a "modest" association between WBGT and exertional heat stroke (EHS), however this was not significant.[1] In another study in 11.3 km races, higher WBGT was associated with increasing exertional heat stroke rates.[22] Additional measures of environmental stress such as the PET (physiological equivalent temperature) have also been associated with MEs and SLMEs such as collapses during a half-marathon.[23,24] While it is generally acknowledged that a higher WBGT could result in more MEs (medical association guidelines),[12] this could be attributed to a lack of heat acclimation/acclimatization. Heat mitigation strategies such as heat acclimation have been shown to decrease core temperature during exercise.[25] Although WBGT was a significant factor associated with higher risk of MEs in our study, we note that the range of WBGT values over the six years was small, and all within the World Athletics "safe" range.[26] This small range and overall "safe" WBGT, could be the reason for finding no association with the SLMEs (20 % of SLMEs were missing for WBGT data), there is the potential that if there are large enough numbers in the future of heat-related illnesses, we could get a better understanding of the role WBGT plays, even in smaller "safe" ranges. The cumulative calculated WBGT for each individual runner may be a more accurate indication of environmental stress for each runner. In future we hope to investigate the specific environmental exposure for each individual runner (specifically using WBGT collected at road level, and not from the national weather stations, and accounting for time on the course) and the association with MEs and specific organ systems affected.

4.1. Strengths/limitations

The strengths of this study are that it is, to our knowledge, the largest study conducted in an ultramarathon race with accurate documentation of medical encounters. The large sample size allowed us to analyze multiple risk factors associated with all MEs and SLMEs. A further strength is that ME data were collected and coded in accordance with the 2019 consensus statement on mass community-based endurance events. We also had additional variables from the entry and race day data that we could investigate as risk factors, unlike many other endurance events which only have demographic and performance variables.

There are also several limitations to consider. First, this was a cross-sectional study and therefore no causalities could be determined. Secondly, we could not investigate detailed intrinsic and extrinsic risk factors for MEs, and future studies could consider introducing pre-race medical screening that could investigate further risk factors such as underlying medical conditions and injuries in race entrants. Another limitation is the lack of data from 2014 regarding previous participation. In future we also plan to determine risk factors associated with MEs by organ system and specific diagnosis. We also could not classify all participants into WBGT categories (resulting in 17 % of MEs and 20 % of SLMEs missing), as we only had the timing mat data for those who finished. The 17–20 % missing ME data for WBGT should not have impacted the results, as there was no significant difference between the finishers vs. non-finishers (Table 2). This information is important to plan and implement preventive strategies to reduce the risk of MEs during ultramarathon running events.

5. Conclusion

The 90 km Comrades marathon race is one the largest ultramarathon running events in the world but also has the highest incidence of MEs and SLMEs compared with other marathon and ultramarathon events.[13] This study identifies novel intrinsic (female, race pace - faster and slower) and extrinsic (higher WBGT and the "down" route) risk factors associated with all MEs in this event. These risk factors can now be considered by the race organizers and the race medical team when planning for future events and could include the development and implementation of prevention strategies such as targeted pre-race medical screening to decrease the risk of MEs and SLMEs during this race.

CRediT authorship contribution statement

Nicola Sewry (NS): study planning, data cleaning, data interpretation, manuscript (first draft), and manuscript editing.

Jeremy Boulter (JB): study planning, data collection, data cleaning, data interpretation, and manuscript editing.

Ishen Seocharan (IS): study planning, data management system, data interpretation, and manuscript editing.

Marlise Dyer (MD): data cleaning, data management, data analysis including statistical analysis, data interpretation, and manuscript editing.

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Confirmation of ethical compliance

Ethical clearance was obtained from the Research Ethics Committee of the University of Pretoria (REC 431/2015).

Data sharing statement

No additional data are available.

Declaration of interest statement

The authors declare that there are no competing interests. JB is the medical director of the Comrades Marathon.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2024.07.008.

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