Medical encounters in a 90km ultramarathon running event:

A 6-year study in 103 131 race starters - SAFER XVII

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The authors declare that there are no competing interests

Abstract

Objective: To determine the incidence and nature of illness-related medical encounters (MEs) at a 90km ultramarathon mass community-based endurance running event

Design: Retrospective, descriptive epidemiological study

Setting: Comrades Marathon (90km), South Africa

Participants: 103 131 race starters over 6 years (2014-2019)

Independent Variables: Incidence of moderate and serious / life-threatening MEs

Main Outcome Measures: All MEs were recorded by race medical doctors on race day each year. MEs were recorded by severity, organ system, and final specific diagnosis (2019 consensus statement definition on mass community-based events). Incidences (I: per 1000 starters; 95%CI) were calculated for MEs.

Results: There were 1971 illness-related MEs, with an overall incidence of 19.1 (18.3-20.0). The incidence for serious / life-threatening MEs was 1.8 (1.6-2.1). Incidences of MEs by organ systems affected were: fluid/electrolyte (8.8; 8.3-9.4), central nervous system (4.0; 3.7-4.5) and gastrointestinal system (2.9; 2.6-3.2). Dehydration (I=7.5: 7.0-8.1) and exercise-associated muscle cramping (EAMC) (I=3.2: 2.9-3.6) were the two most common specific diagnoses.

Conclusion: The incidence of medical encounters in the 90km Comrades Marathon was one of the highest incidences of ME's reported in an endurance running event (1 in 52 starters, and 1 in 556 starters for serious / life-threatening medical encounters). Preventative measures to reduce MEs are needed and further investigations into the risk factors associated with MEs could assist in managing the risk and better prepare athletes, race organisers and medical directors.

Key words:

Running, endurance sports, medical encounters, epidemiology, SAFER study

Introduction

Physical activity has been promoted for many years now, as a preventive and treatment modality for non-communicable diseases (NCDs).[1,2] However, new literature indicates that the intensity of the exercise, specifically more high-intensity endurance exercise, further decreases overall mortality.[3] Following this, it is not surprising that the participation in mass community-based endurance sporting events of older individuals and those with other risk factors for cardiovascular disease (CVD), known CVD and other chronic diseases is common and can be as high as 10-15% of race entrants.[4] This heightens the focus on documenting the incidence and nature of medical encounters (MEs) at these events in order to reduce the risk of MEs, including serious / life-threatening MEs and deaths.[5]

There have been several studies published reporting the incidence of MEs during endurance running events, varying in distances from 10km to ultramarathons,[6-10] but data are often limited to serious / life-threatening medical encounters, and deaths within these events. Investigations reporting sudden cardiac arrests and deaths are often only performed retrospectively through media reports, surveys etc,[11,12] and there is underreporting of "moderate severity"[13] MEs occurring during events.

A recent meta-analysis on long distance running races, determined the incidence of life-threatening events to be 3.19 – 3.68 per 100 000 runners (depending on the distance of event).[14] These data also showed there was no significant difference between the incidence of life-threatening MEs reported in marathon distance events, compared to half-marathon distance events.[14] Whilst this meta-analysis determined no significant differences between the incidence of life-threatening MEs and distances, our data from the Two Oceans Marathon events (a 21.1km, and a 56km) indicate: 1) a large difference in the incidence of MEs

between the two distances (5.14 vs 12.98 per 1000 starters), and 2) a similar incidence for the serious / life-threatening encounters (0.51 vs 0.65 per 1000 starters).[8]

The 90km Comrades Marathon is the largest (by participation numbers) ultramarathon running race in the world. The race attracts 25 000 entrants, with approximately 16 000 starters every year. With the exception of acute renal failure case reports,[15-17] MEs at the Comrades Marathon have not been reported. Anecdotal reports from the medical team each year indicate the incidence of MEs at this 90km event appears to be high, but has yet to be reported.

Therefore, the aim of this descriptive study is to document the incidence and nature of the medical encounters occurring during and immediately after a 90km ultramarathon mass community-based running event (Comrades Marathon) over six years. Furthermore, the severity, main organ system and specific diagnosis of the medical encounters will also be investigated.

Methods

Study Design

This is a retrospective descriptive study of data collected over 6 years.

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.[18] More specifically, this study is a component of the retrospective analysis of data collected on all race starters during the Comrades Marathon from 2014 – 2019 and will serve as the baseline data for future planned interventions. Information regarding registrants, starters and finishers was obtained, with

permission, from the race organizers. These data, which include age, sex, and race speed are in the public domain and are obtainable from the race website. Ethical clearance was obtained from the Research Ethics Committee of the University of Pretoria (REC 431/2015 and 574/2017).

The Comrades Marathon is an annual 90km ultramarathon running event from Durban to Pietermaritzburg (or the other way round, alternating each year, known as the "up" or "down" run), attracting approximately 25 000 entrants each year. The route remains similar each year, with all participants requiring various qualifying times depending on the distance of event - the minimum qualifying distance is a 42.2km event in less than 4:49:59hrs within the 8 months prior to the event. Participants are seeded into starting categories to stagger the start (total stagger time is maximum 10mins) based on qualifying times. All participants must be of at least 20 years of age at time of event (there is no maximum age). The Comrades Marathon also has multiple cut-off times throughout the race where participants are removed from the course if they do not meet the designated cut-off points by the specified time. The event is usually held in early June (autumn / winter), and begins at 5:30AM, and the finish time is 5:30PM.

All race starters of the Comrades Marathon during the study period were considered as participants for this study, and only the starters were included in this study. The did-not-start and did-not-finish rates were calculated, as per the 2019 international consensus statement on mass community-based sports events.[13]

Medical Encounter data collection

Medical facilities on race day consisted of on-route medical stations, ambulances, a physical therapy section, a first aid facility and a medical facility at the finish. All runners reporting

medical encounters (MEs) during or after the race underwent a triage by medical staff and were then admitted for medical management to the appropriate facility. Runners needing medical attention on-route were either taken to the medical facility at the finish (in the case of a moderate medical encounter), or transported to hospital, in the case of a serious life-threatening medical encounter.

Definitions and classification of MEs

For this study, a runner with a medical encounter was defined as "*any runner interacting with the medical team and requiring medical assistance or evaluation, taking place from the official start of the event, up to 24 hours after the official cut-off time of the event*".[13] This is using the definition from the recent consensus statement on definitions of MEs at mass community-based sports events.[13] However, for this study only encounters defined as of moderate and/or serious / life-threatening severity (or death) are reported.[13]

A medical encounter of moderate severity was defined as "*a medical encounter that is significant (severe) enough to result in withdrawal of the athlete from the event following assessment by the medical staff, or is non-life threatening but requires medical assessment and admission to the event medical facilities with supervised medical care, or is non-life threatening but requires referral or transfer to a hospital*" (for further definitions please see the consensus statement).[13]

Illness-related MEs were then further classified into main organ system (and specific diagnosis) as follows:[13] multiple organ, cardiovascular, respiratory, central nervous system, rheumatological, gastrointestinal, genitourinary/renal, endocrine/metabolic, dermatological, psychological/psychiatric, drug use/overdose, and medical illness (other or undiagnosed).

Serious / life-threatening and event-related deaths were also recorded per organ system and specific diagnosis. Within the specific medical encounter diagnoses, "serious cardiovascular" was created by combining the following diagnoses: chest pain (non-specific), acute coronary syndrome, other significant arrhythmia, other abnormality on ECG, murmurs / valvular disease, acute pericarditis, other cardiovascular disease (n=2). All diagnoses of MEs were made by experienced physicians, using clinical criteria.

In summary, each ME was recorded by race medical doctors and nurses on each race day. In some instances, the clinical diagnosis was confirmed by point-of-care testing e.g. hyponatraemia, exertional heatstroke and cardiac arrhythmias. The attending physicians on each race day during the 6-year study period recorded detailed clinical information of each medical encounter in a standardized format and included the system affected as well as the specific final diagnosis.

All medical encounter data was collected in the medical tent on race day on paper-based documents, and then transferred onto REDCap (Research Electronic Data Capture) hosted at the South African Medical Research Council.[19,20] All personal identifiers were removed once the databases (race entry, race day, ME databases) were merged. All serious / life-threatening MEs 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.[13]

Environmental conditions on race days for each year

On race day, hourly data regarding the environmental conditions were collected between 5AM and 5PM from 4 automated weather stations of the South African Weather Services

along the race route. Average wet-bulb globe temperature (WBGT) index, humidity and wind speed were calculated for each of the 6 years (Table 1). The hourly variation of WBGT on race day each year is shown in Supplementary Digital Content Figure 1.

Table 1: Environmental data over the six years during the event

	Temperature (°C)	Humidity (%)	Wind speed (m/s)	WBGT index*
2014	23.1 (6.6)	37 (19.8)	1 (1.1)	16.8 (3.8)
2015	20.1 (5.1)	64.2 (16.8)	1.5 (1.1)	15.3 (2.9)
2016	18.8 (5.8)	54.3 (22.5)	1.3 (1.3)	14.6 (3.3)
2017	19.4 (5.6)	53.7 (19.6)	2.5 (2.2)	14.9 (3.2)
2018	17.3 (4.8)	65.2 (8.6)	2.7 (1.4)	13.8 (2.7)
2019	18.1 (3.9)	67.9 (21.7)	3.1 (2.6)	14.2 (2.2)

*Wet-Bulb Globe Temperature index[20]
Values are mean (SD)

Patient and Public Involvement (PPI)

We did not directly include PPI in this study, but the database used in the study was developed with PPI and is updated by a group that includes patient advisory representatives, including the race organiser and medical director.

Data capturing and statistical analysis

Data capturing was done using REDCap[19,20] which is a web-based application designed to support data capture for research studies. Electronic data was exported and transferred to SAS 9.4 for analysis. From all entrants, the details of runners who started and then the subgroup who finished the race were obtained. The demographics of the starters and finishers were described using numbers and percentages for each year by age group and gender. The incidence (I and 95%CIs) of only illness-related MEs (no injuries) and serious / life-threatening and death MEs were calculated per 1000 runners starting the Comrades Marathon over the six years. Furthermore, the incidences were also calculated for the illness MEs by organ systems. A Poisson regression model was used to compare the incidence of dehydration for years (2014 vs the other 5 years), $p<0.05$ was accepted as significant.

Results

Race entrants, starters, finishers

Over the six years 133 641 runners entered the events, 103 131 started the events (77% of entrants), and 86 284 finished the events (Table 2) (for further details regarding entrants, starters, finishers see Supplementary Digital Content Table 1). The did-not-start rate was 22.8%, and the did-not-finish rate was 16.3% over the six years.

Table 2: Demographics of all race starters and finishers (by gender and year of participation)

Sex	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**All Years**
Starters							
All	**14341**	**16579**	**16846**	**17092**	**19106**	**19167**	**103131**
Males	11333	13122	13286	13541	14924	15374	81580
Females	3008	3457	3560	3551	4182	3793	21551
Finishers							
All	**11917**	**13000**	**14594**	**13852**	**16482**	**16439**	**86284**
Males	9491	10433	11587	11151	13110	13384	69156
Females	2426	2567	3007	2701	3372	3055	17128

Incidence of all illness-related MEs

The number (n) and incidence (I) (per 1000 starters; 95% CI) of all illness-related MEs (including both moderate and serious / life-threatening / death) and specific serious / life-threatening and death per year is shown in Table 3. There were 1971 illness-related MEs over the six years, with an incidence of 19.1 (18.3-20.0) per 1000 starters (1 in 52 starters). The year with the highest incidence of MEs was 2014, with an incidence of 23.3 (20.9-25.9) per 1000 starters (1 in 43 starters). This was also the year with the highest temperature (23.1) and WBGT (16.8).

Table 3: Incidence of all illness-related medical encounters and serious / life-threatening and death (per 1000 starters; 95% CI) per year, and overall.

	Year (n = starters)													
	2014 (n=14 341)		2015 (n=16 579)		2016 (n=16 846)		2017 (n=17 092)		2018 (n=19 106)		2019 (n=19 167)		All Years (n=103 131)	
	n	I (95% CI)	n	I (95% CI)	n	I (95% CI)	n	I (95% CI)	n	I (95% CI)	n	I (95% CI)	n	I (95% CI)
All Illness-Related Medical Encounters	334	23.3 (20.9-25.9)	287	17.3 (15.4-19.4)	368	21.8 (19.7-24.2)	336	19.7 (17.7-21.9)	319	16.7 (15.0-18.6)	327	17.1 (15.3-19.0)	1971	19.1 (18.3-20.0)
Serious / Life-Threatening and death	26	1.8 (1.2-2.7)	18	1.1 (0.7-1.7)	27	1.6 (1.1-2.3)	24	1.4 (0.9-2.1)	54	2.8 (2.2-3.7)	40	2.1 (1.5-2.8)	189	1.8 (1.6-2.1)

*There was only 1 death

Incidence of illness-related MEs (includes both moderate and serious / life-threatening / death) by organ system and final diagnosis

The number (n) and incidence (I; 95% CI) per 1000 starters of illness-related MEs by main organ system and by final diagnosis is shown in Table 4. The incidence of illness-related MEs was highest in the category "multiple organs" (I=9.2; 8.6-9.8), followed by the central nervous system (I=4.0; 3.7-4.5) and the gastrointestinal system (I=2.9; 2.6-3.2). The sub-category of illnesses with the highest incidence were fluid and electrolyte abnormalities (I=8.8; 8.3-9.4), and the most common specific diagnoses were dehydration (I=7.5; 7.0-8.1), exercise-associated muscle cramping (EAMC) (I=3.2; 2.9-3.6) and nausea / vomiting (I=2.1; 1.9-2.4) (Table 4). The incidence of dehydration compared to year, and year compared to WBGT are illustrated in Figure 1. The incidence of dehydration was significantly associated with year, and also corresponded to the WBGT (p=0.0001). The year with the highest incidence of dehydration (2014) was significantly different to 2018 and 2019, which also had the lowest WBGT.

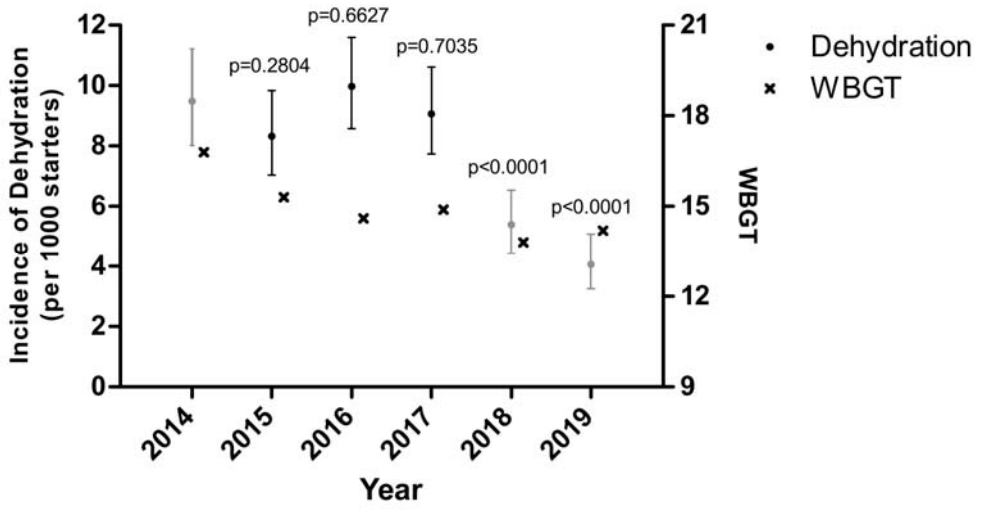

Figure 1. Comparison of the incidence of dehydration and WBGT to year. WBGT: Wet-bulb globe temperature. Incidence and 95% confidence interval presented. Grey points: the 2014 grey point is the reference category, 2018 and 2019 grey points are significantly different from 2014. Black points: nonsignificantly different from reference category. P-value: compared with 2014 as the reference category.

Table 4: Number (n) and incidence (I; 95% CI) per 1000 starters of illness-related medical encounters by main organ system and by final diagnosis in all starters for the 6-year period.

Main organ system and final diagnosis	**All Starters (n = 103 131)**		
	n	**I**	**95% CI**
Multiple Organs	**948**	**9.20**	**8.6-9.8**
Heat Illness	33	0.30	0.2-0.5
Hypothermia	26	0.30	0.2-0.4
Hyperthermia / exertional heat stroke	7	0.07	
Rhabdomyolysis	2	0.02	
Fluid and Electrolyte Disorders	912	8.80	8.3-9.4
All dehydration	778	7.50	7.0-8.1
Hyponatraemia	34	0.30	0.2-0.5
Other electrolyte disorders	100	1.00	0.8-1.2
Cardiovascular	**164**	**1.60**	**1.4-1.9**
Exercise associated postural hypotension (EAPH)	104	1.00	0.8-1.2
Syncope (non-specific)	12	0.10	0.1-0.2
Serious Cardiovascular	48	0.50	0.4-0.6
Respiratory	**23**	**0.20**	**0.1-0.3**
Respiratory tract infection	9	0.09	
Asthma / allergy	7	0.07	

Other respiratory illness not otherwise specified	7	0.07	
Central Nervous System	**417**	**4.00**	**3.7-4.5**
Exercise-associated muscle cramps (EAMC)	330	3.20	2.9-3.6
Dizziness / nausea (non-specific)	62	0.60	0.5-0.8
Confusion (non-specific)	15	0.10	0.1-0.2
Other CNS	10	0.10	0.1-0.2
Rheumatological	**1**	**0.01**	
Gastrointestinal	**295**	**2.90**	**2.6-3.2**
Nausea / vomiting (non-specific)	220	2.10	1.9-2.4
Abdominal pain (non-specific)	20	0.20	0.1-0.3
Gastrointestinal infection	19	0.20	0.1-0.3
Diarrhoea	22	0.20	0.1-0.3
Other gastrointestinal illness	11	0.10	0.1-0.2
Genitourinary/Renal	**37**	**0.40**	**0.3-0.5**
Haematuria	25	0.20	0.2-0.4
Other urinary illness	12	0.10	0.1-0.2
Endocrine/Metabolic	**13**	**0.10**	**0.1-0.2**
Hypoglycaemia (non-specific)	11	0.10	0.1-0.2
Other endocrine disorder	2	0.02	
Dermatological	**3**	**0.03**	
Psychological / Psychiatric	**2**	**0.02**	
Drug use / Overdose	**1**	**0.01**	
Medical Illness (Other or undiagnosed)	**66**	**0.60**	**0.5-0.8**
Tired athlete (non-specific)	55	0.50	0.4-0.7
Other medical illness	11	0.10	0.1-0.2

*n<10 did not have 95% CI due to small numbers

Incidence of serious / life-threatening ME's and deaths

There were 189 serious / life-threatening MEs (I=1.8; 1.6-2.1) (1 in 546 starters), which included two sudden cardiac arrests (SCA) post-race, and one death (multiple organ failure, post-race). The incidence of deaths in the Comrades Marathon is therefore 0.01 per 1000 starters (1 in 100 000 starters) and the incidence of SCA is 0.02 per 1000 starters. Whilst 2014 had the highest incidence of illness MEs, the highest incidence of serious / life-threatening / death was in 2018 (I=2.8; 2.2-3.7) (1 in 354 starters). The serious / life-threatening MEs are presented, by main organ system, in Supplementary Digital Content Table 2. The highest incidence of serious / life-threatening MEs was reported in the multiple

organ systems (I=0.8; 0.6-1.0) followed by the cardiovascular system (I=0.5; 0.4-0.6). Most of "multiple organ system" were primarily made up of dehydration (n=59) and hyponatraemia (n=13), the "cardiovascular" events were as follows: exercise-associated postural hypotension (EAPH) (n=16), syncope (n=9), chest pain – non-specific (n=8), acute coronary syndrome (n=4), cardiac arrhythmias (n=8), other cardiac disease (murmurs, acute pericarditis; n=5).

Discussion

This study is the first to document the overall incidence of illness-related medical encounters (MEs) at the 90km Comrades Marathon, a mass community-based ultramarathon running event. The main findings of the study were: 1) the overall incidence of illness-related MEs was 19.1 (18.3-20.0) per 1000 starters, 2) the incidence of serious / life-threatening MEs was 1.8 (1.6-2.1) per 1000 starters, 3) the organ systems affected most were the fluid/electrolyte, central nervous system and gastrointestinal systems, 4) dehydration and EAMC were the two most common specific medical diagnoses and 5) dehydration was related to environmental conditions.

The Comrades Marathon is unique for its long road running distance, 90km. We show, for the first time, that this race is also unique and has a particularly high incidence of illness-related MEs, with 1 in 52 race starters developing a medical encounter. When comparing this incidence to that of other similar events (which used the same definitions, with the exception of including musculoskeletal injuries), the Comrades Marathon runner (I=12.98), has a 4X higher risk of an ME compared with a 21.1km Two Oceans runner (I=5.14), and a 1.5X higher risk of an ME compared to a 56km Two Oceans runner.[8] The Twin Cities Marathon also reported data on MEs, and if only the "moderate" illness-related encounters are

compared, the incidence is 13.7 per 1000 entrants (acknowledging the differences in definitions and using entrants and not starters).[9] The Baltimore Marathon also report on their MEs, where for MEs of at least moderate severity (withdrew from the race) an incidence of 13.2 per 1000 participants can be calculated (again acknowledging the methodological differences).[21] This illustrates the large difference the risk of a medical encounter between the marathon distance event and the 90km Comrades ultramarathon.

Serious / life-threatening and deaths at the Comrades Marathon are also more common. Although there was only one death over the six years studied at the Comrades Marathon (death rate of 1 / 100 000 starters), this is higher than that reported in a recent meta-analysis, of 0.39 per 100 000 runners,[14] and 0.24 per 100 000 of events in Sweden[22], but lower that that reported for the 21.1km runners at Two Oceans (5 / 100 000 starters),[8] and the Twin Cities Marathon (1.23 / 100 000 entrants).[9] Although reporting death rates is important, we recognize that death rates can vary and are dependent on the rapid and appropriate use of automated electronic defibrillators. We believe that a better statistic is to document and compare incidence of serious / life-threatening MEs.[13] The incidence of serious / life-threatening MEs at the Comrades Marathon was 1.8 per 1000 starters, and this is substantially higher when compared to the Twin Cities Marathon (0.03),[9] the Two Oceans 21.1km event (0.51) and the Two Oceans 56km event (0.65).[8] Both the incidence of all MEs and serious / life-threatening MEs appear to be related to race distance using our Two Oceans data (Figure 2a and 2b).[8]

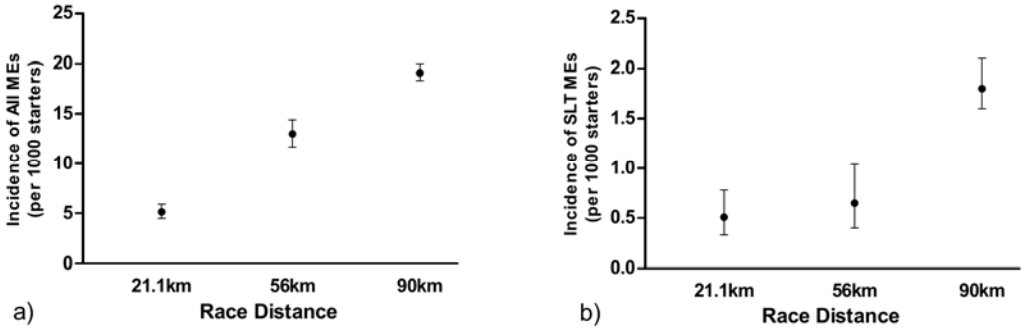

Figure 2. A, The incidence of all MEs across different race distances. (B) Incidence of serious/life-threatening MEs across different race distances. SLTs: serious/life-threatening MEs data from 21.1-km to 56-km events are from previously published data (Schwabe K, et al. Br J Sports Med. 2014).

This clear trend in increased risk of MEs by race distance, should be further investigated in more events, different race distances (e.g. 10km, 42km) and in different countries / regions. Other risk factors affecting the ME rate should also be investigated.

The most common "organ system" affected was "multiple organs" (with the fluid and electrolyte abnormalities contributing the largest: I=8.8), followed by the central nervous system (predominantly EAMC; I=4.0) and the gastrointestinal system (I=2.9). When comparing these data to the Two Oceans races (cardiovascular system: I=1.93; dermatological: I=1.37; central nervous system, including EAMC; I=1.05)[8], this illustrates that race distance not only affects the incidence of MEs, but also the type of MEs presenting in the medical tent during and immediately after the event. We do recognise that there may be several other reasons for this observation besides race distance. These could include differences in the race entrant populations (age, sex, running experience, pre-race qualification, and pre-race medical history, including chronic disease risk). Furthermore, it must be noted, that there is a first aid and physiotherapy medical tent in addition to the main medical tent at the Comrades Marathon, which could account for the low reporting of

dermatological MEs (which are much higher at the Two Oceans), as runners with these could have reported to the first aid tent instead of the medical tent, due to the low severity of these MEs.

On race day, environmental conditions differ from year to year and this could have an effect on the incidence of some MEs. We note that the year with the highest WBGT and temperature was 2014, which also had the highest ME rate (23.6 / 1000 starters). Previous studies have shown that heat (there are various measures of heat including WBGT and PET) has an effect on MEs, specific MEs and other outcomes such as not-finishing a race.[23,24] In our study, we show that dehydration, which was the most common specific ME, had the highest incidence in the year with the lowest WBGT. Whilst there are many other factors that could be confounders (e.g. age, gender, race route etc.), this should be further investigated in future studies where independent risk factors associated with MEs can be explored in a multi-variate model.

There are several strengths of this study. Firstly, medical encounter data was recorded by attending medical doctors in the medical tent, using uniform medical forms, over these six years. The event had the same medical director for all six years of data collection and analysis, which increased the standardisation of the training of the race day medical staff. Secondly, this is one of the largest studies to document MEs in ultramarathon events and we used the definitions and reporting methods that were recently recommended in a consensus document.[13] The limitations of the study are that there were multiple doctors attending on race day, and therefore we acknowledge the potential for discrepancies, and the field-based nature of the study (compared to laboratory-based diagnoses), however there was diagnostic point-of-care testing when needed. The doctors also used a paper-based system, which could

have led to some inconsistencies compared to an electronic system. These data are also estimates, and could not be adjusted for the correlation in the data encountered, due to runners taking part in more than one year's event, as runners could not be linked from one year to the next.

Future studies, owing to the large number of race starters and medical encounters, will allow for investigation of multiple risk factors (including age, sex, race day WBGT, race pace, up/down run) for these MEs, using multi-variate models. The profile of race day medical encounters could then be predicted, allowing race organisers and medical directors the opportunity to better prepare for the specific MEs, and also develop and implement prevention strategies, such as pre-race medical screening including the researched risk factors, to make these races safer.

Summary and Conclusions

The incidence of illness-related medical encounters at the 90km Comrades Marathon is very high compared to other distance running races (19.1 / 1000 starters, approximately 1 in 52 starters). In particular, the incidence of serious / life-threatening medical encounters (1.8 / 1000 starters) was also very high. The most common organ systems affected were the fluid and electrolyte (mainly dehydration), central nervous system (mainly EAMC) and gastrointestinal systems. Further investigations into the risk factors associated with MEs in this event could assist in designing and implementing preventative measures to reduce the risk of medical encounters and also allow race organisers and medical directors to plan medical care better.

What are the new findings?

- The incidence of illness-related medical encounters during/immediately after the event the 90km Comrades Marathon is high for endurance runners (1 in 52 starters)
- 1 in 556 starters at the 90km Comrades Marathon event will develop a serious / life-threatening medical encounter

Practical Implications

- Race medical directors of ultramarathon events can expect a high rate of all medical encounters (mainly dehydration and EAMC) and serious / life-threatening medical encounters
- These data will assist medical directors in planning medical care at these ultramarathon distance races, particularly as it relates to staff compliment (number and skill sets of staff), medical facilities and pre-race advice to runners
- These data will set the basis for further clinical studies investigating the risk factors associated with illness-related medical encounters during ultramarathon running events

References

1. Khan KM, Thompson AM, Blair SN, et al. Sport and exercise as contributors to the health of nations. *Lancet.* 2012;380(9836):59-64.
2. Kohl HW, 3rd, Craig CL, Lambert EV, et al. The pandemic of physical inactivity: global action for public health. *Lancet.* 2012;380(9838):294-305.
3. Strain T, Wijndaele K, Dempsey PC, et al. Wearable-device-measured physical activity and future health risk. *Nature Med.* 2020;26(9):1385-1391.

4. Schwabe K, Schwellnus M, Swanevelder S, et al. Leisure athletes at risk of medical complications: outcomes of pre-participation screening among 15,778 endurance runners - SAFER VII. *Physic Sportsmed.* 2018:1-9.

5. RunSignup. Race Trends: Annual Statistical Report. *https://runsignupcom/Trends.* 2019. Accessed February 28, 2020.

6. Breslow RG, Shrestha S, Feroe AG, et al. Medical tent utilization at 10-km road races: injury, illness, and influencing factors. *Med Sci Sport Exerc.* 2019;51(12):2451-2457.

7. Lüning H, Mangelus C, Carlström E, et al. Incidence and characteristics of severe exercise-associated collapse at the world's largest half-marathon. *PLOS ONE.* 2019;14(6):e0217465.

8. Schwabe K, Schwellnus M, Derman W, et al. Medical complications and deaths in 21 and 56 km road race runners: a 4-year prospective study in 65 865 runners - SAFER study I. *Br J Sports Med.* 2014;48(11):912-918.

9. Roberts WO. A 12-yr profile of medical injury and illness for the Twin Cities Marathon. *Med Sci Sports Exerc.* 2000;32(9):1549-1555.

10. Shirakawa T, Tanaka H, Kinoshi T, et al. Analysis of sudden cardiac arrest during marathon races in Japan. *Int J Clin Med.* 2017;8(7):9.

11. Roberts WO, Roberts DM, Lunos S. Marathon related cardiac arrest risk differences in men and women. *Br J Sports Med.* 2013;47(3):168-171.

12. Webner D, DuPrey KM, Drezner JA, et al. Sudden cardiac arrest and death in United States marathons. *Med Sci Sports Exerc.* 2012;44(10):1843-1845.

13. Schwellnus M, Kipps C, Roberts WO, et al. Medical encounters (including injury and illness) at mass community-based endurance sports events: an international consensus

statement on definitions and methods of data recording and reporting. *Br J Sports Med.* 2019;53:1048-1055.

14. Gerardin B, Guedeney P, Bellemain-Appaix A, et al. Life-threatening and major cardiac events during long-distance races: updates from the prospective RACE PARIS registry with a systematic review and meta-analysis. *Europ J Prev Cardiol.* 2020:2047487320943001.

15. Boulter J, Noakes TD, Hew-Butler T. Acute renal failure in four Comrades Marathon runners ingesting the same electrolyte supplement: coincidence or causation? *South Afr Med J.* 2011;101(12):876-878.

16. Seedat YK, Aboo N, Naicker S, et al. Acute renal failure in the "Comrades Marathon" runners. *Renal Failure.* 1989;11(4):209-212.

17. van Zyl-Smit R, Mills P, Vogelpoel L. Unrecognised acute renal failure following the comrades marathon. *South Afr Med J.* 2000;90(1):39-40.

18. Schwellnus M, Derman W. The quest to reduce the risk of adverse medical events in exercising individuals: introducing the SAFER (Strategies to reduce Adverse medical events For the ExerciseR) studies. *Br J Sports Med.* 2014;48(11):869-870.

19. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: Building an international community of software platform partners. *J Biomed Inform.* 2019;95:103208.

20. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009;42(2):377-381.

21. Tang N, Kraus CK, Brill JD, et al. Hospital-based event medical support for the Baltimore Marathon, 2002−2005. *Prehosp Emerg Care.* 2008;12(3):320-326.

22. Nilson F, Börjesson M. Mortality in long-distance running races in Sweden - 2007–2016. *PLOS ONE.* 2018;13(4):e0195626.

23. Carlström E, Borjesson M, Palm G, et al. Medical emergencies during a half marathon race–the influence of weather. *Int J Sports Med.* 2019;40(05):312-316.

24. Grundstein AJ, Hosokawa Y, Casa DJ, et al. Influence of race performance and environmental conditions on exertional heat stroke prevalence among runners participating in a warm weather road race. *Front Sports Act Living.* 2019;1(42).