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A high incidence of serious life-threatening cardiovascular medical encounters during a marathon (2014–2019) calls for prevention strategies: SAFER XL

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ABSTRACT

Objective: The aim of this study was to determine the incidence and nature (severity and type by organ system and specific diagnosis) of all medical encounters (MEs), including serious/life-threatening MEs (SLMEs) during a South African road marathon.

Methods: This descriptive study was a retrospective analysis of data collected over 6 years at the Cape Town Marathon from 2014 to 2019, which included 40 446 starters. All MEs were collected and described as per the consensus statement for mass community-based sporting events. Incidences (I; per 1000 starters; 95% CI) are described for all MEs, SLMEs, and by organ system and specific diagnosis.

Results: The incidence of all MEs was 8.7 (95% CI: 7.8–9.6) per 1000 starters. The largest contributor to all MEs, by organ system affected, was cardiovascular-related, with an incidence of 1.8 (95% CI: 1.4–2.2), where exercise-associated postural hypotension was the most common specific diagnosis (I = 1.3; 95% CI: 1.0–1.7). The incidence of all SLMEs was 1.0 (95% CI: 0.7–1.4) making up 11.7% (41/350) of all MEs. The incidence of SLMEs by organ system was highest in the cardiovascular system (I = 0.4; 95% CI: 0.3–0.7), with acute coronary syndrome (ACS) (I = 0.2; 95% CI: 0.1–0.4) the most common specific diagnosis. There were no sudden cardiac deaths (SCD) nor sudden cardiac arrests (SCA).

Conclusion: There was a high proportion of cardiovascular-related medical encounters, as well as SLMEs. We recommend that event organizers and race medical directors investigate prevention strategies to mitigate against risk of SLMEs, specifically acute cardiovascular SLMEs.

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Introduction

It is well-established that regular participation in physical activity has numerous health benefits, including a reduction in risk of premature cardiovascular mortality and morbidity [1–5]. Therefore, participation in physical activity has increased across the globe, which is reflected in increased participation in mass community-based sporting events such as marathon running. Marathon running is a prolonged moderate- to high-intensity exercise that is associated with a potentially higher risk of medical encounters (MEs) during a race [6,7]. In 2019, an international consensus statement aimed at standardizing the reporting of the type and severity of medical encounters (MEs) at endurance events was published [8]. Some of the most serious MEs described in endurance sporting events include acute cardiovascular events such as acute coronary syndrome (ACS) (e.g. acute myocardial infarction, unstable angina), sudden cardiac arrest (SCA), and sudden cardiac death (SCD) [6,9–15]. The incidence (per 100 000 starters) of SCD and SCA in distance running races has been well documented, with incidences varying between 0.3 and 5 per 100 000 participants for SCD [16–18] and 0.54–2.5 per 100 000 race participants for SCA [9,16,19]. In a recent meta-analysis, comprising eight distance running registries (16 223 826 runners), the incidence of SCD was 0.39 per 100 000 and for SCA was 0.82 per 100 000 [18].

In general, fewer studies in distance runners reported the incidence of acute cardiovascular MEs other than SCD or SCA during races. In one of the largest studies of more than a million runners across 46 Parisian long-distance running events (42.2 km and other distance races comprising 21.1 km and other distances), the incidence of serious/major cardiac events was 2.33 per 100 000 and this was almost double the incidence of SCA (1.67 per 100 000) [18]. In four other studies, the incidence (per 100 000 race starters) of acute serious/life-threatening cardiovascular-related MEs was reported as follows: 16.1 km race (4.3) [20], 21.1 km race (13) [13], 56 km race (11) [13], and 90 km race (50) [21]. It is important to determine the incidence of serious/life-threatening MEs

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(SLMEs) in the cardiovascular system and specifically ACS in distance running events because acute coronary syndrome, for example, is a medical emergency [22] and poses a high risk for SCA and SCD.

Besides SLMEs affecting the cardiovascular system, other non-cardiac SLMEs can also occur, including exertional heatstroke [7,13,17,23,24], hyponatremia [13,25–28], exertional rhabdomyolysis [29], and acute kidney injury [29,30]. In addition to serious/life-threatening MEs (SLMEs), other MEs of moderate severity during distance running events also add to the potential burden of MEs that race medical directors and organizers must prepare for. Two studies on road running events have shown an incidence of all MEs ranges between 8.27 and 19 per 1000 starters during/after the event, illustrating a much larger burden (when including all moderate encounters) on the race/event organizers, as well as the athlete [13,21].

At the time of data collection, the Cape Town Marathon attracts approximately 13,000 recreational and professional runners in the full marathon (42.2 km), 10000 for the 10 km and 1000 runners in the trail run division from around the world annually. However, the incidence and nature of all MEs, SLMEs (by organ system and specific diagnosis, including ACS) during and immediately after this marathon is currently unknown. This information is important for both race organizers and medical staff to provide insights for improving race infrastructure planning and preparation, race day resource allocation and distribution, as well as implementing risk mitigation strategies.

The aim of this study was to determine the incidence and nature (severity and type by organ system and specific diagnosis) of all MEs, including SLMEs, during and immediately after the Cape Town Marathon.

Materials and methods

Study design

This descriptive study is a retrospective analysis of data collected over 6 years (2014–2019).

Setting

The Cape Town Marathon is a 42.2 km standard marathon race held in the city of Cape Town, South Africa, first held in 2007. Available distances include the full marathon (42.2 km), a 10 km and 5 km race, and two trail runs of 46 km and 22 km respectively (only the marathon is included in this study). The marathon is held on a fast and flat course, starting and finishing in Green Point (a metropolitan seaside suburb), near the Cape Town Stadium. The Cape Town Marathon is also the host of the South African marathon championships. This marathon attracts large numbers of first-time marathon runners and allows 6.5 h for completion. Participants come from diverse socio-economic circumstances, which may be relevant when studying the illness and injury profile of the event.

There are no qualifying times for this marathon event and therefore the race attracts all levels of participants including novice, recreational, and elite runners, from age 20 years and upwards. The event is held in the spring season between mid-September to mid-October annually. This study forms part of an ongoing series of studies focusing on '*Strategies to Reduce Adverse Medical Events for the Exerciser (SAFER),*' the SAFER studies [31].

Participants and data collection

All the race starters of the annual Cape Town Marathon from 2014 to 2019 were included as study participants. For purposes of researching this population, specific permission to investigate the incidence and nature of MEs during the Cape Town Marathon was obtained from the Research Ethics Committee at the University (REC: xxx) and XX University (xxx). The dataset contains information regarding starters and finishers that were obtained, with permission, from the race organizers. These de-identified data including age, sex, and race timing data, are in the public domain and were obtainable from the event website. Participants were not required to undergo any medical testing prior to the event.

Medical encounter data

The event was supported by an experienced medical team, under the management of a race medical director, who provided medical care and support on race day. The medical team comprised a pre-hospital and on-route components, as well as the end-of-race facility in close proximity to the finish line. There was a mixture of static and mobile medical resources along the route at 5 km intervals for the first 15 km, and closer together for the 18-22 km and 37–42.2 km areas. Mobile medical resources (ambulances) were stationed between these points to ensure optimal response times to medical incidents. Each medical point had advanced life support capabilities, staffed by a doctor/nurse team, assisted by mobile physical therapists. Members of this medical team provided medical support in the event of any acute medical emergencies or injuries on race day. The medical team was comprised of trained medical professionals, including doctors, nurses, and physiotherapists. Staffing included emergency and sports medicine practitioners as well as an Intensive Care Unit (ICU) and emergency center trained nurses. The mobile response team was made up of advanced, intermediate, and basic life support paramedics and first aiders in vehicles affording diverse accessibility options namely, ambulances, rapid-response vehicles and golf carts. The end medical facility comprised of a 20-bed race hospital with dedicated high-acuity area and resources. Diagnoses were made clinically by qualified medical staff and specific diagnoses were confirmed by special investigations e.g. heatstroke (core temperature and clinical signs), rhabdomyolysis (serum CK elevation and clinical signs), hyponatremia (serum sodium concentrations and clinical signs). All MEs requiring hospital referral and admission were followed up for up to seven days by a senior nursing member of the team to confirm the clinical diagnosis.

ME data were entered into either an electronic or paper-based record system by using the standardized medical incident form. The author team converted data onto a standardized spreadsheet, using the international consensus statement [8] to classify and record all MEs from race/event day in each year of the study. All data were transferred into a digital format for processing and analysis.

Definition and classification of MEs and data analysis

For the purposes of this study, a Medical Encounter was defined as "*a reported medical problem that is an 'interaction between the medical team and a race participant 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"* using the international consensus definitions [8]. MEs were further subdivided into minor, moderate and SLMEs and illness-related medical encounters were subclassified by main organ system affected as follows: multiple organ (including fluid and electrolyte abnormalities), cardiovascular system, respiratory system, nervous system, gastrointestinal system, dermatological system, metabolic system and renal/urogenital system, musculoskeletal system, psychological and other unspecified medical illness [8]. The severity of the ME was also classified according to the consensus and only moderate and SLMEs were included for this analysis. The definition of a moderate ME is:

> '*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*'.

A SLME is further distinguished by the following definition: '*a medical encounter that is known to be life threatening and requires immediate emergency medical treatment with either admission to a high-care (intensive care and observation) medical area at the event or transport (with or without admission) to a hospital."* [8]

Data regarding environmental conditions on race day were obtained from the South Africa Weather Services (SAWS) retrospectively by the research team. Temperature (°C), humidity (%), wind speed (m/s) data were obtained from five weather stations along the route measured between 6am-2 pm and the average over these five stations was used to calculate these variables on race days. The wet-bulb globe temperature (WBGT) index was calculated using air temperature, humidity, wind speed and solar radiation whilst the risk level for exertional heat-related illness was determined using international guidelines provided by World Athletics and the International Institute for Race Medicine Web which are as follows: WBGT of <18°C = low risk, 18–23°C = moderate risk, 23–28°C = high risk and ≥28°C = very high risk [32]. It should be noted that the medical team measured the WBGT on race day at the start, halfway and at the finish. WBGT monitoring was part of the heat management plan, and higher temperatures would trigger additional resources such as extra ice, water, or event race cancellation.

Statistical analysis

All data were de-identified, stored securely, and were made available to the research team. All the data from the runner and medical encounter dataset was entered into a Microsoft Excel spread sheet and then analyzed using SAS statistical software (version 9.4, Cary NC). Descriptive statistics (overall and per year) for starters and finishers include numbers (%). The dependent variable in the model was the binary-scaled response variable related to the question regarding MEs. The Poisson distribution with the PROC GENMOD statement and an associated log link option were used for analysis. Univariate unadjusted incidence (per 1000 starters and 95% confidence interval [CIs]) was reported for overall ME, ME by organ system and final diagnosis. Similarly, univariate unadjusted incidences were also calculated for SLMEs. The total sample ($n = 40\ 446$) was used to estimate the overall incidence. The incidence is presented per 1000 race starters as per the international consensus statement on mass community sports events.

Table 1. The demographics of all race starters and finishers from 2014 – 2019 (n; %).

		2014 n (%)	2015 n (%)	2016 n (%)	2017 n (%)	2018 n (%)	2019 n (%)	Total n (%)
Total race starters	All	3495 (100)	4421 (100)	6300 (100)	8363 (100)	7927 (100)	9940 (100)	40446 (100)
Males	All	2296 (65.7)	2895 (65.5)	4011 (63.7)	5392 (64.5)	5213 (65.8)	6474 (65.1)	26281 (65.0)
	≤30 yrs	352 (10)	441 (10)	664 (10.5)	706 (8.4)	651 (8.2)	763 (7.7)	3577 (8.8)
	31–40 yrs	712 (20.4)	958 (21.7)	1411 (22.4)	1996 (23.9)	1916 (24.2)	2438 (24.5)	9431 (23.3)
	41–50 yrs	751 (21.5)	922 (20.9)	1239 (19.7)	1736 (20.8)	1675 (21.1)	2103 (21.2)	8426 (20.8)
	>50 yrs	481 (13.8)	574 (13)	697 (11.1)	954 (11.4)	971 (12.2)	1170 (11.8)	4847 (12.0)
Females	All	1199 (34.3)	1526 (34.5)	2289 (36.3)	2971 (35.5)	2714 (34.2)	3466 (34.9)	14165 (35.0)
	≤30 yrs	183 (5.2)	244 (5.5)	480 (7.6)	459 (5.5)	385 (4.9)	519 (5.2)	2270 (5.6)
	31–40 yrs	400 (11.4)	558 (12.6)	833 (13.2)	1170 (14)	1074 (13.5)	1398 (14.1)	5433 (13.4)
	41–50 yrs	422 (12.1)	480 (10.9)	681 (10.8)	941 (11.3)	872 (11.0)	1066 (10.7)	4462 (11.0)
	>50 yrs	194 (5.6)	244 (5.5)	295 (4.7)	401 (4.8)	383 (4.8)	483 (4.9)	2000 (4.9)
Total Finishers	All	3406 (100)	4267 (100)	6117 (100)	8024 (100)	7672 (100)	9612 (100)	39098 (100)
Males	All	2237 (65.7)	2803 (65.7)	3919 (64.1)	5210 (64.9)	5060 (66.0)	6289 (65.4)	25518 (65.3)
	≤30 yrs	345 (10.1)	425 (10)	572 (9.4)	680 (8.5)	632 (8.2)	741 (7.7)	3395 (8.7)
	31–40 yrs	696 (20.4)	931 (21.8)	1411 (23.1)	1940 (24.2)	1865 (24.3)	2382 (24.8)	9225 (23.6)
	41–50 yrs	732 (21.5)	897 (21)	1239 (20.3)	1680 (20.9)	1634 (21.3)	2045 (21.3)	8227 (21.0)
	>50 yrs	464 (13.6)	550 (12.9)	697 (11.4)	910 (11.3)	929 (12.1)	1121 (11.7)	4671 (11.9)
Females	All	1169 (34.3)	1464 (34.3)	2198 (35.9)	2814 (35.1)	2612 (34.0)	3323 (34.6)	13580 (34.7)
	≤30 yrs	179 (5.3)	235 (5.5)	389 (6.4)	437 (5.4)	373 (4.9)	500 (5.2)	2113 (5.4)
	31–40 yrs	392 (11.5)	542 (12.7)	833 (13.6)	1113 (13.9)	1035 (13.5)	1347 (14.0)	5262 (13.5)
	41–50 yrs	410 (12.0)	458 (10.7)	681 (11.1)	900 (11.2)	840 (10.9)	1022 (10.6)	4311 (11.0)
	>50 yrs	188 (5.5)	229 (5.4)	295 (4.8)	364 (4.5)	364 (4.7)	454 (4.7)	1894 (4.8)

Results

The profile of the starters and finishers for the six years of the Cape Town Marathon with a total of 40,446 race-starters is presented in Table 1.

Participant demographics

There was a predominance of male race starters and finishers over the six years (65%). Most male and female runners were in the 31–40 years age-category. Total number of non-finishers over the 6 years were 1348, with an overall did-not-finish rate of 3.3%, with the rate for males being 2.9% and females 4.1%.

Environmental conditions on race day

The environmental conditions are presented in Table 2.

The wet-bulb globe temperature (WBGT) index was consistent with a low risk of hyperthermia over the six-year period. It is important to note that 2015 and 2017 were the years with a higher WBGT, 15.8 and 15.3 respectively.

Incidence of medical encounters (MEs) and serious/life-threatening medical encounters (SLMEs) on race day

The incidence of all MEs (combined moderate and severe) and SLMEs for each year are presented in Table 3. The overall incidence of all MEs was 8.7 (95% CI: 7.8–9.6) per 1000 starters, and the overall incidence of SLMEs was 1.0 (95% CI: 0.7–1.4) per 1000 starters. SLMEs made up 11.7% (41/350) of all MEs. The highest incidence of all MEs was in 2017, with the highest incidence of SLMEs in 2015. There were no SCD and SCA during the six years.

Number and incidence of all MEs by organ system and specific diagnosis

The incidence and number of all MEs by main organ system affected and specific diagnosis of illnesses are presented in Table 4. The largest contributor to all MEs, by organ system affected, were cardiovascular conditions (I = 1.8; 95% CI: 1.4–2.2), with exercise-associated postural hypotension being the most common specific diagnosis (I = 1.3; 95% CI: 1.0–1.7). The incidence of dehydration was 0.8 (95% CI: 0.6–1.2) per 1000 starters. The second most common organ system affected was the musculoskeletal system (I = 1.4; 95% CI: 1.1–1.9), followed by the gastrointestinal system (I = 1.3; 95% CI: 1.0–1.7) and the combined respiratory/ENT system with an incidence of 0.9 (95% CI: 0.6–1.2). In the musculoskeletal system, the most common anatomical locations for injury were the knee (*n* = 12) and ankle (*n* = 10).

Number and incidence of SLMEs by organ system and specific diagnosis

The incidence and number of SLMEs by main organ system affected and specific diagnosis of illnesses are presented in Table 5. The most common SLMEs were in the cardiovascular system (*n* = 17; I = 0.4; 95% CI: 0.3–0.7) (male = 11, female = 6; all age >31 yrs), with acute coronary syndrome (e.g. myocardial infarction, unstable angina) (*n* = 7; I = 0.2; 95% CI: 0.1–0.4) (male = 4, female = 3; all age >31 yrs) being the most common specific diagnosis. This was followed by an acute kidney injury and dehydration (both *n* = 6; I = 0.1; 95% CI: 0.1–0.3) (male = 5, female = 1; age <31 yrs = 2, age >31 yrs = 4). Hyperthermia/exertional heat stroke (*n* = 3) was less common in this race, and there were no cases of hyponatremia or exertional rhabdomyolysis. The age and sex distribution were varied across the organ systems as well as within the specific diagnosis categories (including younger and both sexes, and therefore not limited to older males).

Discussion

This study serves as one of the first describing not only the incidence but importantly the type (by organ system and specific diagnosis) of all MEs and SLMEs in a 42.2 km marathon event in South Africa. The first finding was that the incidence of all MEs was 8.7 (95% CI: 7.8–9.6) per 1000 starters (1 in 115 race starters). The most common organ systems affected for all

Table 2. Environmental conditions on race day for the six year period.

Year	Temperature (°C)	Humidity (%)	Windspeed (m/s)	WBGT index	Risk level of Hyperthermia
2014	17.17	56.94	3.73	13.68	Low
2015	21.01	42.18	1.45	15.86	Low
2016	16.30	51.44	2.55	13.19	Low
2017	20.03	54.91	1.33	15.30	Low
2018	16.25	61.51	2.42	13.17	Low
2019	15.74	69.20	3.44	12.88	Low

*WBGT: wet-bulb globe temperature [40].

Table 3. The number and incidence of medical encounters (all and serious/life-threatening) per 1000 starters each year from 2014 to 2019.

	2014		2015		2016		2017		2018		2019		All years	
Medical Encounters	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 Medical Encounters	32	10.3 (7.4-14.3)	47	12.4 (9.6-16.2)	32	5.6 (4.0-7.7)	99	13.2 (10.9-15.9)	51	6.9 (5.3-9.0)	48	5.9 (4.6-7.7)	350	8.7 (7.8-9.6)
Serious/life-threatening MEs	4	1.1 (0.4-3.1)	8	1.8 (0.1-3.6)	3	0.5 (0.2-1.5)	11	1.3 (0.7-2.4)	4	0.5 (0.2-1.3)	11	1.1 (0.6-2.0)	41	1.0 (0.7-1.4)

*I: incidence per 1000 starters.
MEs: medical encounters.

Table 4. The number and incidence (I; 95% CI; per 1000 race starters) of all medical encounters by organ system and specific diagnosis.

	All Starters (n = 40446)		
Main organ system and final diagnosis	n	I	95%CI
Multiple Organ System	48	1.2	0.9-1.6
Heat Illness			
Hypothermia	1	–	–
Hyperthermia/exertional heat stroke	4	–	–
Fluid/Electrolyte			
Dehydration (moderate: >5% to < 7% body weight loss)	34	0.8	0.6–1.2
Dehydration (severe: >7% body weight loss)	9	0.2	0.1–0.4
Cardiovascular System	71	1.8	1.4–2.2
Exercise Associated Postural Hypotension (EAPH)	51	1.3	1.0–1.7
Syncope (nonspecific)	7	0.2	0.1–0.4
Chest pain (nonspecific)	4	–	–
Acute coronary syndrome (e.g. myocardial infarction, unstable angina)	7	0.2	0.1-0.4
Other significant arrhythmia	1	–	–
Acute myocarditis (viral)	1	–	–
Respiratory/ENT System	35	0.9	0.6–1.2
Other upper respiratory tract infection	9	0.2	0.1–0.4
Other lower respiratory tract infection	2	–	–
Asthma – allergic	8	0.2	0.1–0.4
Asthma – exercise induced only	1	–	–
Other respiratory illness not otherwise specified	15	0.4	0.2–0.6
Central Nervous System	52	1.3	1.0–1.7
Severe EAMC (generalized, altered mental status or with systemic symptoms	24	0.6	0.4–0.9
Dizziness/nausea (nonspecific)	18	0.6	0.4–0.9
Epilepsy	2	–	–
Headache not otherwise specified	8	0.2	0.1–0.4
Gastrointestinal	54	1.3	1.0–1.7
Nausea/vomiting (nonspecific)	18	0.4	0.3–0.7
Abdominal pain (nonspecific)	6	0.1	0.1–0.3
Gastroenteritis (including food poisoning)	16	0.4	0.2–0.6
Exercise associated gastritis/reflux	3	–	–
Gastritis/peptic ulceration – non exercise/NSAID related	11	0.3	0.2–0.5
Genito-urinary	7	0.2	0.1–0.4
Other genitourinary infection	1	–	–
Acute kidney injury	6	0.1	0.1–0.3
Endocrine/Metabolic System	6	0.1	0.1–0.3
Hypoglycaemia (nonspecific)	6	0.1	0.1–0.3
Dermatological	10	0.2	0.1–0.5
Skin chafing/blister	7	0.2	0.1–0.4
Laceration	3	–	–
Psychological/Psychiatric	0	0	0
Musculoskeletal	58	1.4	1.1-1.9
Medical Illness (Other or undiagnosed)	9	0.2	0.1-0.4

*Diagnoses with an n of < 5 do not have 95% CIs.
ENT: ear nose and throat.
- Incidence (95%CI) was not calculated for cases where *n* < 5 to avoid interpretation when there is low confidence in the precision of the estimate.

MEs were the cardiovascular (I = 1.8; 95% CI: 1.4–2.2), musculoskeletal system (I = 1.4; 95% CI: 1.1–1.9), GIT (gastrointestinal) system (I = 1.30; 95% CI: 1.0–1.70), CNS (central nervous) system (I = 1.30; 95% CI: 1.0–1.70), multiple-organ systems 1.2 (95% CI: 0.9–1.6) and the respiratory/ENT system (I = 0.9; 95% CI: 0.6–1.2). The most common specific diagnoses of all MEs were EAPH (exercise-associated postural hypotension) (I = 1.3; 95% CI: 1.0–1.7), followed by moderate dehydration (0.8), EAMC (exercise-associated muscle cramps) (0.6) and dizziness/nausea (0.6).

A second and the main novel finding was that the incidence of SLMEs was 1.0 (95% CI: 0.7–1.4) per 1000 starters, making up 11.7% (41/350) of all MEs. Although no SCD or SCA was recorded during the six-year period, the incidence of SLMEs by organ system was highest in the cardiovascular system (I = 0.4; 95% CI: 0.3–0.7), with acute coronary syndrome (e.g. myocardial infarction, unstable angina) (*n* = 7; I = 0.2; 95% CI: 0.1–0.4) being the most common specific diagnosis.

Incidence of all MEs and MEs by organ system and specific diagnosis

The incidence of MEs has been reported in several studies [7,17,33] but in these reports, the definition of ME was not standardized, and this makes comparison to our findings difficult. When comparing our findings to other endurance distance running events, where the same definition of ME was used, the overall incidence (per 1000 race starters) of all MEs in our study (I = 8.7) was lower compared to that reported for longer race distances such as the 56 km Two Oceans ultramarathon (I = 13) and the 90 km Comrades Marathon (I = 19.1), but higher than in shorter distance races such as the 21.1 km Two Oceans Half Marathon in 2008–2011 (I = 5.1) and the 16.1

Table 5. The number and incidence (I; 95% CI; per 1000 race starters) of serious/life-threatening medical encounters by organ system and specific diagnosis.

Main organ system and final diagnosis	All Starters (n = 40446)		
	n	I	95% CI
Multiple Organs	9	0.2	0.1–0.4
Dehydration (severe: >7% body weight loss)	6	0.1	0.1–0.3
Hyperthermia/exertional heat stroke	3	–	–
Cardiovascular System	17	0.4	0.3–0.7
Acute coronary syndrome (e.g. myocardial infarction, unstable angina)	7	0.2	0.1–0.4
Exercise Associated Postural Hypotension (EAPH)	5	0.1	0.1–0.3
Chest pain (nonspecific)	3	–	–
Other significant arrhythmia	1	–	–
Acute myocarditis (viral)	1	–	–
Respiratory/ENT System	3	–	–
Other upper respiratory tract infection	1	–	–
Other lower respiratory tract infection	2	–	–
Central Nervous System	3	–	–
Epilepsy	2	–	–
Headache not otherwise specified	1	–	–
Gastrointestinal	1	–	–
Gastroenteritis (including food poisoning)	1	–	–
Genito-urinary	6	0.1	0.1–0.3
Acute kidney injury	6	0.1	0.1–0.3
Endocrine/Metabolic System	2	–	–
Hypoglycaemia (nonspecific)	2	–	–

ENT: ear nose and throat.
- Incidence (95%CI) was not calculated for cases where $n < 5$ to avoid interpretation when there is low confidence in the precision of the estimate.
The diagnoses include both serious as well as life-threatening medical encounters.

km Dam-tot-Damloop (I = 2.8) [20]. Similarly, 3.8 per 1000 starters required on-site medical care at the Army 10 miler road race from 1998 to 2004, but in this study minor MEs were also included [33]. Therefore, the first main observation from this study is that our data support the general observation that the longer the race distance, the higher the incidence of all MEs. The clinical implication of this finding is that longer race distances are associated with a higher incidence of all MEs and race medical directors can use this information to plan medical services at running events by estimating the incidence of all MEs, based on the race distance of the event they cover.

The most common MEs by organ systems affected (per 1000 race starters) were cardiovascular (I = 1.8), musculoskeletal system (I = 1.4), GIT (gastrointestinal) system (I = 1.3), CNS (central nervous) system (I = 1.3), multiple-organ systems (I = 1.2) and the Respiratory/Ear, Nose and throat (ENT) system (I = 0.9) per 1000 starters. The three most common organ systems where MES are reported in our study (cardiovascular, musculoskeletal and GIT systems) correlate with similar ME data by organ system, previously reported in other distance running events. These three organ systems are all placed in the top five organ systems across other running events [13,20,21].

The most common MEs by specific diagnoses were exercise-associated postural hypotension (EAPH; I = 1.3), dehydration (I = 0.8) and severe EAMC (exercise-associated muscle cramps; I = 0.6). Similarly, the Two Oceans half and ultra-marathons reported exercise-associated collapse (postural hypotension), dermatological conditions, musculoskeletal injuries and serious exercise-associated muscle cramping as the most common specific medical complications. The Comrades Marathon in comparison over the same 6 year period documented a very similar incidence of 1.6 per 1000 for organ-specific cardiovascular MEs with EAPH representing the highest in this group with an incidence of 1.0 per 1000 starters [21]. The most common gastrointestinal-related MEs were nonspecific nausea/vomiting followed by gastroenteritis with an incidence of 0.4 per 1000 starters respectively. Gastric distress as well as changes in regular eating plans on race day are potential contributing factors to these symptoms [34]. Overall, the distribution of organ systems affected and specific diagnoses in the Cape Town Marathon follows similar trends, noting that there are no unique diagnoses in this event that the organizers need to specifically be concerned about compared to other events. Again, race medical directors can use this information to not only plan for the types of medical encounters expected at running events but also consider conditions affecting these organ systems when planning an educational intervention program to mitigate against the risk of MEs.

Incidence of all SLMEs, and SLMEs by organ system and specific diagnosis

The overall incidence (per 1000 race starters) of SLMEs at the 42.2 km Cape Town Marathon was 1.0 and these made up 11.7% of all MEs. In comparison to studies using the same definition of SLMEs, the incidence of SLMEs reported in our study is about two times higher than the incidence reported at the 21.1 km Two Oceans half-marathon (I = 0.5), and 1.5X higher that the 56 km Two Oceans ultra-marathon (I = 0.7) (5% of all MEs) [35], but lower than the 90 km Comrades marathon (I = 1.8) (9% of all MEs) [21]. In a recent systematic review [18], the incidence of SLMEs at distance running events across half and full marathon distances was between 0.032–0.037 per 1000 starters (much lower than Two Oceans), which is substantially lower than the incidence of SLMEs in our study. The reasons for this are not clear, but are likely related to differences in the definitions of MEs and SLMEs across studies, specifically those published before the recommendations of the international consensus statement in 2019 [8]. It is important to note that in the Two Oceans 56 km marathon race the overall incidence of MEs was higher than in our study, but the incidence of SLMEs was lower than that reported in our study. Potential factors that could account for this observation are speculative but may include the non-qualifying or seeding prerequisites for 42.2 km event and the large field of novice marathon participants, which could mean that the athlete's level of race preparation, experience, and conditioning. Furthermore, the pre-race medical history profile of race entrants and starters (e.g. history of known underlying cardiovascular disease or risk factors for cardiovascular disease) could differ between these races and this is another potential factor that could account for the difference in the incidence of SLMEs described. Finally, we note that the races differ according to season, where the Two Oceans 56 km ultra-marathon is held in April and the 42.2 km Cape Town Marathon in October where environmental exposure can influence the incidence and nature of all MEs and SLMEs. The period studied revealed a low-risk environmental conditions over all six years, but this is not always a predictable set of circumstances for the scheduled time of the Cape Town Marathon.

Sudden deaths reported at marathon events are relatively uncommon, with an incidence varying between 0.3 and 5 per 100 000 participants [17]. A study in the USA described the overall death rate in USA marathons between 2000 and 2009 to be 0.75 per 100 000 finishers with the most common cause being cardiac, followed by exercise-associated hyponatremia, hyperthermia, and brain aneurysm [36]. Although no SCD or SCA were reported over the 6 year period in our study, the incidence of SLMEs in the cardiovascular system was high (40 per 100 000 race starters). It is interesting to compare the incidence of major cardiovascular events and SLMEs across events but variations in the definition of SLME was not consistent across events prior to the endurance event consensus statement guidelines in 2019. However, the incidence of serious or major cardiac ME can be compared in studies using the same definition of SLMEs and this shows a particularly high incidence of 50, 40, 13 and 11 (per 100 000) in the Comrades Marathon, Cape Town Marathon, Two Oceans 21.1 km and Two Oceans Ultra 56 km respectively [13,21]. These incidences are considerably higher than the incidence of major cardiac ME reported in the Paris registry studies where an incidence of 2.3 per 100 000 (95% CI 1.6–3.4 per 100 000 runners) was described.

For specific diagnoses of SLMEs, we show an incidence of ACS (including unstable angina and myocardial infarction as per ME consensus statement) of 20 per 100 000. Acute coronary syndrome is a known precursor of and risk for SCA and SCD. There are only a few studies where the specific diagnoses of SLMEs affecting the cardiovascular system are reported and not just SCA or SCD. This incidence of ACS we report in our study is 4-5X higher than the incidence reported for the diagnosis of 'ischaemic heart disease' in the 21.1 km and 56 km Two Oceans marathons [13] and approximately 10X higher than an estimated incidence of ACS of 1.02 per 100 000 reported in the large PARIS registry study [18]. Therefore, whilst the risk of SCA and SCD in our study appears lower, the incidence of ACS, which could lead to SCA or SCD is very high. The reasons for the high incidence as well as preventative measures to reduce the risk of acute cardiovascular SLMEs, specifically ACS, in this race need further investigation [10,37,38]. For example, race organizers could consider implementing a pre-race medical screening and education intervention program because, in a previous study, we reported that such a program successfully reduced SLMEs by 64% (adjusted for age group and sex) [39]. It is important to note that the implementation of pre-race medical screening should not disqualify runners based on medical history, but should be combined with educational information to prompt runners to seek medical clearance if deemed to be at higher risk based on risk stratification following their medical history. The educational intervention also assists in educating the runner on common MEs and how to prevent them.

Environmental conditions

It has been documented that environmental conditions play an important role in the incidence of moderate severity and SLMEs [25,26]. The WBGT is often used as a measure of environmental exposure and utilizes air temperature, humidity, solar radiation, and wind speed in its calculation measure [40]. The Heat stress index also assists race medical directors with planning and resource allocation as part of the event hydration and ice plan. During this study of the Cape Town Marathon, the WBGT index was consistent with a low risk of hyperthermia over the six years. There is also evidence to suggest a higher incidence of MEs related to environmental conditions such as warmer weather. A recent study from Boston Marathon between 2015 and 2019 showed an incidence of 37 per 100 0000 whilst higher overall ME rates were reported at the Houston Marathon in 2000 with warm (25 degree Celsius) and 93% humidity, with an incidence of all MEs at 36 per 1000 starters [25]. Whilst another study also reported a high rate of medical encounters (181 per 1000 starters and 214 per 1000 finishers) at a marathon held in hot conditions with a maximum temperature of 30 degrees and starting relative humidity of 97% [26]. We suggest that race organizers continue to monitor the predicted environmental conditions for the event, to ensure preventative medical initiatives and resources (such as ice baths in hot conditions) are implemented when necessary.

Strengths and limitations

The strengths of this study include the large sample size of 40,446 race starters, allowing a better understanding of the incidence and types (including the specific diagnoses) of all MEs and SLMEs over a lengthy period of 6 years. Medical reporting was done by highly skilled and trained doctors and nurses who work in the field of emergency and sports medicine. The benefit of retrospective coding using the medical encounter consensus statement facilitates advancement in useful comparisons to previously published data and future comparisons [8]. Some limitations of the study included the fact that the ME data were also de-identified and anonymized, prohibiting tracing to the individual runner race day profile information (due to ethical and data protection concerns), this could have been useful to assess risk factors for specific medical encounters. This study was thus descriptive and did not investigate reasons for the potential increase or decrease in risk of MEs and this should be explored in future studies.

Conclusion

The main findings were that the overall incidence of all MEs was 8.70 (95% CI: 7.80–9.60) per 1000 starters, and the overall incidence of serious/life-threatening MEs was 1.00 (95% CI: 0.70–1.40) per 1000 starters. SLMEs made up 11.7% (41/350) of all MEs. Although there were no SCDs, during the six years, the incidence was very high in relation to the previously reported incidences of SCD, SCA or ACS (including myocardial ischemic events). This finding is a key focus area of prevention strategies that can be introduced to further reduce the risk of SLME. The clinical implications of the findings of this study are that event organizers and race medical directors should use the information for planning medical care and to optimize participant safety and patient care at mass participation endurance events. Race medical directors can also use these findings as motivation for resource planning and approach risk mitigation with proactive pre-race medical screening and educational intervention strategies and the use of innovative messaging platforms to inform and better prepare endurance runners.

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