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Medical complications and deaths in 21 and 56 km road race runners: a 4-year prospective study in 65 865 runners—SAFER study I

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ABSTRACT

Background Cardiac arrest and sudden death during distance-running events have been reported but other medical complications, including serious life-threatening complications have not been well described.

Objective To document the incidence and nature of medical complications during 21 and 56 km running races.

Design Prospective study.

Setting Two Oceans Marathon races (21 and 56 km races).

Participants 65 865 race starters (39 511—21 km runners, 26 354—56 km runners).

Methods Medical complications (defined as any runner requiring assessment by a doctor at the race medical facility or a local hospital on race day) were recorded in each of the 4 years of the study period. Complications were further subdivided into serious (potentially life-threatening) complications and deaths and were also analysed by system and final diagnosis.

Results In the 4 years, 545 medical complications were recorded, resulting in an overall incidence (per 1000 race starters) of 8.27. The incidence of serious (potentially life-threatening) medical complications was 0.56 (37 serious complications). Two deaths occurred in 21 km runners (incidence of 0.05). The most common specific medical complications were exercise-associated collapse (postural hypotension), dermatological conditions, musculoskeletal injuries and serious exercise-associated muscle cramping.

Conclusions The incidence of medical complications was higher in 56 km runners but sudden cardiac deaths only occurred in 21 km runners. Serious medical complications were as common in 21 km as in 56 km runners. Risk factors for medical complications need to be determined in 21 and 56 km runners to plan strategies to reduce the risk of adverse medical events in endurance runners.

INTRODUCTION

Regular participation in physical activity is well established as an important lifestyle intervention for primary and secondary prevention of chronic non-communicable diseases.[1 2] In this regard, recreational distance running as a form of regular physical activity has become popular globally. However, it is well documented that vigorous physical activity, such as distance running, may be associated with medical complications that can affect a variety of organ systems.[3] Of particular interest is the fact that vigorous exercise may act as a trigger for acute myocardial infarction and sudden death in younger and older runners.[4] There is considerable interest to determine the risk of sudden death during exercise, in particular during distance running events such as the half-marathon (21 km) and the marathon (42 km).[4–11] This information is important as it may identify risk factors for sudden death during running, and therefore point to possible measures to prevent sudden death and other adverse medical events in endurance runners.

While sudden cardiac death has enjoyed the focus of a number of clinical studies, the incidence of other medical complications during running, including non-cardiac but serious life-threatening medical complications, has not been well studied. Data are limited to a few studies,[12] mostly dating back to over 10 years ago.[13–15]

In one of the most comprehensive studies in marathon runners, the 12-year injury and illness data were reported for over 80 000 race entrants.[15] The main finding of this study was that the incidence of medical encounters (complications per 1000 race entrants) was 18.9, and the most common medical complications were exercise-associated collapse (11.3) followed by dermatological complications (4.1) and musculoskeletal complications (3.4). The incidence of cardiac arrest and sudden death was 1.2 per 100 000 runners (1 in 83 333 runners).[15] In only one other study, medical complications were reported in a cohort of 396 ultramarathon runners participating in a 7-day staged (240 km) event.[16] These data show a very high medical complication rate of 3871 per 1000 runners, mostly affecting the skin and the musculoskeletal system. However, these data cannot be compared to a single day community-based distance running event.

There are few data describing the incidence and risk factors for some specific non-cardiac serious medical complications including hyponatraemia,[17–20] acute renal failure[21] and heat stroke.[20 22 23]

Therefore, apart from the data reported in the single study on marathon runners,[15] a detailed analysis of the incidence and nature of all medical complications during 21 and 56 km (ultramarathon) running, particularly in other organ systems has not been reported in the literature. This information is important to reduce the risk of any adverse medical events (deaths, serious and less serious) in endurance runners, and to plan medical care of large community-based endurance running events.

The Two Oceans Marathon races comprise a number of mass community-based running events that take place annually during late summer in

Cape Town, South Africa. These races, which attract about 25 000 runners every year, comprise a short (5–8 km) fun-run, two trail runs (10 and 22 km), a half-marathon (21 km) and an ultramarathon (56 km). The two main events that attract the majority of endurance runners are the 21 km race and the 56 km race. Entries to the 21 km race are open to novice runners and require no qualifying time, while the entry for the 56 km race requires completion of any one of the following qualifying times: a standard 42 km marathon in <5 h, 50 km in <6.5 h, 56 km in <7 h, 90 km in <12 h or a 100 km race in <13.5 h.

The aim of this study was to document the incidence and nature of medical complications during the Two Oceans races (21 and 56 km). In addition, we wanted to record the incidence of medical complications in different organ systems and by racing distance (21 vs 56 km). This is the first of a series of studies that are aimed at reducing the risk of an adverse medical event in endurance runners: the SAFER (*S*trategies to reduce *A*dverse medical events *F*or the *E*xercise*R*) studies.[24]

METHODS

Type of study

This was a prospective study over 4 years.

Participants and demographics

All the participants of the Two Oceans Marathon races (includes a 21 km half-marathon and a 56 km ultramarathon) over a 4-year period (2008–2011) were considered as participants. Information regarding registrants, starters and finishers was obtained, with permission, from the race organisers. These data, which include age, gender, previous participation (and number of completed races) in the Two Oceans races, are in the public domain and are obtainable from the race website. Registrations for these races typically open 3–5 months before the races.

During the 4-year study period, a total of 81 345 runners registered for the races. Of the total registrants, 65 865runners started the races (81.1% of registrations), and only these runners were participants in this study. While there is no upper age limit, entrants are required to be 16 years or older for the 21 km race and 20 years or older for the 56 km race. The demographics (by year of participation and gender of all the race starters in the 4-year study period) are depicted in table 1. Our study cohort therefore consisted of 41 026 male starters and 24 839 female starters of the races.

Medical data collection (classification, medical complications, hospital admissions and deaths)

A medical team, responsible for medical care on race day, is assembled 6–8 months before race day to prepare and plan for medical care on race day. Medical facilities on race day consisted of on-route medical stations, and a physical therapy and a medical facility at the finish. All runners with medical complications during or after the race underwent a triage by emergency medical staff and were then admitted for full assessment and management at either the medical or physiotherapy facilities. Runners with serious or life-threatening medical complications that occurred on route during the race were attended to by emergency response teams and these runners were immediately transported to the nearest local hospital if required. Emergency medical staff attended to serious/life-threatening medical complications that occurred at the end of the race in the medical facility at the end of the race and these runners were then transported to local hospitals if required.

For the purposes of this study, a runner with a medical complication was defined as ‘any runner who required medical care on race day that was severe enough to warrant a medical assessment by a doctor, either in the medical facility at the end of the race, on route at the medical stations, or at one of the referral hospitals (for runners that were assessed by medical staff on the route)’. This definition is similar to that reported in one previous study,[15] with the exception that minor medical encounters (not requiring an assessment by a medical doctor) were not included in our study. Examples of such encounters would be runners seeking assistance at first aid stations along the route, and admissions to the physical therapy section of the medical facility at the end of the race. Furthermore, not all runners with exercise-associated muscle cramps (EAMC) were included in the present study—only those with EAMC that required an assessment by a medical doctor because of EAMC together with associated symptoms (confusion, dizziness, nausea and vomiting, diffuse cramping or collapse) were included. In this study, this group will be referred to as serious EAMC (sEAMC).

A serious (life-threatening) complication was defined as ‘a medical complication that could result in death unless urgently diagnosed and treated’. The following serious medical complications (by organ system) were included in the study: cardiovascular (ischaemic heart disease, arrhythmias and myocarditis), renal (acute renal failure), fluid, electrolyte and acid–base abnormalities (symptomatic hyponatraemia, metabolic acidosis and severe dehydration), metabolic abnormalities (hypoglycaemic coma and diabetic coma), respiratory (severe asthma and pulmonary oedema), thermoregulatory abnormalities (heat stroke) and central nervous system (convulsions). Deaths that occurred during the 4-year period were also recorded.

Accurate and detailed clinical information of each medical complication was recorded by attending race physicians during the 4-year study period in a standardised format and included the system affected and the specific final diagnosis.

Data collection of environmental conditions on race days for each year

Data concerning the environmental conditions between 6:00 and 12:00 on race day of each year including the temperature, humidity, rainfall, cloud cover and wind speed were obtained from the database of the South African Weather Services and are depicted in table 2. The Wet Bulb Globe Temperature (WBGT) index was calculated from these data.

Calculation of the incidence of all medical complications, serious life-threatening medical complications and deaths

For the purposes of this study, the incidence of all medical complications, serious life-threatening medical complications and deaths were calculated as runners with medical complications/ deaths per 1000 runners who started the races. We chose the denominator as the number of runners who started the race because most studies reporting deaths and medical complications report this denominator and we wanted to relate our findings to those of other studies. Data reported per 1000 starters are also

Table 1 Demographics of all race starters (by gender and year of participation)

Gender	2008	2009	2010	2011	All runners
Males	10 142	10 596	10 708	9580	41 026
Females	5600	6248	6650	6341	24 839

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Table 2 Environmental conditions on race day for each year

	Temperature (°C)	Humidity (%)	Rainfall (mm)	Wind speed (knots)	WBGT index*
2008	18.2 (1.9)	77 (8)	0	9.6 (2.4)	16.5 (2.4)
2009	17.1 (1.4)	83 (7)	0	7.8 (1.0)	15.4 (1.6)
2010	16.3 (0.8)	93 (3)	0	3.5 (0.6)	15.2 (1.4)
2011	11.5 (2.1)	87 (2)	0	1.5 (1.3)	13.5 (2.9)

Values are mean (SD).
*Wet Bulb Globe Temperature (WBGT) index—calculated using temperature (°C), humidity, time of day and cloud cover data.

important for medical staff to plan medical care at races such as these, as this format allows organisers to estimate the anticipated number and nature of medical complications at races. Further analysis of the incidence was also conducted in subgroups as follows: race type (21 or 56 km race), year of observation (2008–2011) reflecting environmental conditions (table 2), organ system affected and the final diagnosis for the more common medical complications. However, we were also able to document the number of finishers per race over the 4-year study period, and could also include some preliminary analyses on factors that could determine the ability to finish the race.

Statistical analysis of data

All the data from the runner and medical complications database were entered into an Excel spreadsheet (Microsoft 2010) and then analysed using the SAS Enterprise Guide (V6.1) statistical programme. If included, log linear modelling was applied to model the starter characteristics. A logistic regression was used to model the non-finisher characteristics, separately for 21 and 56 km runners. The association between finishers/non-finishers and runner characteristics (race type, gender and age) were explored. Crude incidence rates are reported overall and by year, race type, organ system and final diagnosis. Categorical data analyses comparing 21 and 56 km races used the Fisher exact and χ^2 tests. Statistical significance was accepted at $p<0.05$.

RESULTS

Race finishers

Of the runners who started the races, 64 420 finished the races within the required cut-off times (97.8% runners; table 3). In the 21 km race, 39 111of the 39 511 starters finished the races (99%), and in the 56 km race 25 309 of the 26 354 starters finished the races (96%).

Table 3 Demographics of participation (starters and finishers) by year of the race and type of race participation

Race type	2008	2009	2010	2011	All (2008–2011)
Total starters					
All	15 742	16 844	17 358	15 921	65 865
21 km	9723	10 696	9550	9542	39 511
56 km	6019	6148	7808	6379	26 354
Total finishers					
All	15 541	16 635	17 071	15 173	64 420
21 km	9714	10 689	9539	9169	39 111
56 km	5827	5946	7532	6004	25 309

In a logistic regression analysis (data not shown) gender and age were two factors that were significantly associated with non-finishing. In both race types, the odds for a woman not to finish was higher than for a man not to finish ($OR_{56\ km}=1.31$; $OR_{21\ km}=2.82$). In the 21 km race for every 10-year increase in age, the odds for not finishing increased with 35% ($OR_{21\ km}=1.35$), and in the 56 km race for every 10-year increase in age the odds for not finishing increased with only 15% ($OR_{56\ km}=1.15$).

Incidence of deaths

In the 4-year period, two deaths were documented. Both deaths occurred in 21 km runners and therefore the incidence of deaths in 21 km runners was 0.05 per 1000 21 km runners (1 in 20 000 21 km runners starting the race).

Incidence of medical complications (all complications and the subgroup of serious life-threatening medical complications), by race type and year of observation

The incidences of all (serious and less-serious) medical complications and the subgroup of serious life-threatening medical complications in each year of the study and race type are depicted in table 4.

Incidence of all medical complications

In the 4-year observation period, a total of 545 medical complications (serious and less serious) were documented in 65 865 runners starting the races (0.827% of all runners starting the races). Therefore, the incidence of any medical complications was 8.27 per 1000 runners (95% CIs 7.61 to 9.00; 1 in 121 race starters). Of the 545 medical complications, 203 were documented in the 39 511 21 km runners (5.14 per 1000 runners; 95% CI 4.48 to 5.90; 1 in 195 race starters) and 342 were documented in the 26 354 56 km runners (12.98 per 1000 runners; 95% CI 11.67 to 14.43 1 in 77 race starters). Thus, the incidence of medical complications (per 1000 runners) was higher in 56 km runners compared with 21 km runners ($p<0.0001$).

Incidence of all serious life-threatening medical complications

In the 4-year observation period, a subgroup of 37 medical complications were classified as serious life-threatening (0.056% of all runners starting the races). The serious life-threatening complications included the following: ischaemic heart disease (n=3; including successfully resuscitated sudden cardiac arrest), myocarditis (n=2), serious cardiac arrhythmias (n=2), symptomatic hyponatraemia (n=9), serious metabolic complications (n=5), serious heat-related disorders (hyperthermia=6, hypothermia=1; n=7), pulmonary oedema (n=2), serious fluid, electrolyte or acid–base abnormalities (hyperkalaemia=1, metabolic acidosis=1, significant dehydration=2; n=4), bronchospasm (n=2) and convulsions (n=1). The incidence of all serious medical complications was 0.56 per 1000 runners (95% CI 0.41 to 0.78; 1 in 1 786 race starters). Of the 37 serious medical complications, 20 were documented in the 21 km runners (0.51 per 1000 runners; 95% CI 0.33 to 0.78; 1 in 1961 race starters) and 17 were documented in the 56 km runners (0.65 per 1000 runners; 95% CI 0.40 to 1.04; 1 in 1538 race starters). There was no significant difference in the incidence of serious medical complications between 56 km and 21 km runners ($p=0.4612$).

Table 4 Incidences (per 1000 runners starting the race: 95% CI) of any medical complications and serious medical complications by race type in the 4 years of study

	2008	2009	2010	2011	All years
All					
All	7.11 (5.91 to 8.56)	8.43 (7.15 to 9.94)	7.55 (6.36 to 8.96)	10.05 (8.61 to 11.73)	8.27 (7.61 to 9.00)
Serious	0.57 (0.30 to 1.10)	0.42 (0.20 to 0.87)	0.63 (0.35 to 1.14)	0.63 (0.34 to 1.17)	0.56 (0.41 to 0.78)
21 km					
All	4.73 (3.54 to 6.32)	3.93 (2.90 to 5.31)	5.03 (3.79 to 6.67)	7.02 (5.53 to 8.92)	5.14 (4.48 to 5.90)
Serious	0.51 (0.21 to 1.24)	0.47 (0.19 to 1.12)	0.63 (0.28 to 1.40)	0.42 (0.16 to 1.12)	0.51 (0.33 to 0.78)
56 km					
All	10.97 (8.61 to 12.93)	16.27 (13.37 to 19.79)	10.63 (8.57 to 13.18)	14.58 (11.90 to 17.86)	12.98 (11.67 to 14.43)
Serious	0.66 (0.25 to 1.39)	0.33 (0.08 to 1.30)	0.64 (0.27 to 1.54)	0.94 (0.42 to 2.09)	0.65 (0.40 to 1.04)

The incidence of medical complications by organ system affected and final diagnosis

The incidence of specific medical complications in all the runners (per 1000 runners) by the organ system affected, and by the final diagnosis is depicted in table 5.

The incidence of specific medical complications in 21 and 56 km runners (per 1000 runners) by the organ system affected, and by the final diagnosis is depicted in table 6.

The incidence of cardiovascular, musculoskeletal, metabolic, gastrointestinal and respiratory complications was significantly higher in 56 km runners compared with 21 km runners (table 6). For specific diagnoses, the incidence of postural hypotension, sEAMC and severe fatigue was higher in 56 km runners compared with 21 km runners (table 6). It is important to note that the incidence of serious cardiac conditions was not significantly different between the two races.

DISCUSSION

To the best of our knowledge, this is the largest and most comprehensive prospective study documenting the incidence and nature of medical complications (including deaths, serious life-threatening medical complications and complications by the system affected) during 21 and 56 km distance running. The first main finding of this study is that incidence of death in 21 km runners was 0.05/1000 runners (1 in 20 000 runners starting the race). Second, the incidence of serious (life-threatening) medical complications in both races combined was 0.56 (1 in 1785 runners starting the race), and this was similar in the 21 km runners (0.51) and 56 km runners (0.65). Third, the common medical complications in distance runners (per 1000 runners) by organ system affected, and by final diagnosis, were as follows: postural hypotension (1.75), followed by dermatological complications (1.37), musculoskeletal complications (1.31), serious sEAMC (0.91) and gastrointestinal complications (0.88). Fourth, we show that the overall incidence of medical complications is significantly higher in 56 km runners compared with 21 km runners, and that the incidence of specific medical complications by organ system affected, and the clinical profile of the final diagnosis differs between the two race types. Finally, our data show female runners and older runners are less likely to complete an endurance race (21 and 56 km race).

In our study, both deaths occurred in 21 km runners. Therefore, we can only compare our observed death rate to other studies in 21 km runners. Our observed death rate of 5/100 000 runners is about 18 times higher than the death rate (0.27/100 000) reported in only one other study in 21 km runners in the USA.[8] The high death rate in 21 km runners in our study is of great concern and is not well explained. However, there are a number of possible reasons for our observed high death rate. First, there are significant methodological differences in the data collection procedures between our study and that conducted by Kim *et al*.[8] We prospectively followed all runners who entered the race over the 4-year period and this is in contrast to retrospective data obtained in the US study, which was from the race medical data and press reports. Therefore, it is possible that under-reporting could have occurred in the previous study. However, the total number of races and therefore runners studied was substantially higher in the study by Kim *et al*.[8] Finally, from the data described in the US study, it is not clear if any screening took place before races, and whether there were any specific entry requirements.

In our study, apart from age (≥16 years) there are no other restrictions to participate in the 21 km race. Therefore, the race may attract runners of all ages who do not necessarily perform regular exercise, runners who are not necessarily well prepared and have not undergone any prerace medical screening. In addition, runners may have risk factors for cardiovascular disease, or may have other chronic medical conditions. Our data, from both races, indicate that about 30% of runners are older than 40 years (data not shown). Although older age is a well-established risk factor for cardiovascular disease, this is not likely to explain the increased risk of sudden death in 21 km runners in our study. However, it is possible that the prevalence of other risk factors for cardiovascular disease may be higher in 21 km compared with 56 km runners. In our population there are no data on cardiovascular risk factors, and no pre-exercise screening was conducted. Data concerning other possible risk factors for underlying chronic disease in this group would also be important to obtain and will be the focus of future studies.

The second main finding in our study was that we documented an overall incidence of serious (life-threatening) complications in 0.56/1000 runners starting the race. Notably, this was similar in the 21 km (0.51) and 56 km (0.65) races. There are very few published data documenting serious (life-threatening) complications during distance running. In one study, an incidence of more serious medical complications was reported as 0.03/1000 marathon runners entering a race.[15] We can only compare the results of our study in 21 and 56 km runners to that reported in Roberts's study. The present study indicates that the incidence of serious medical complications during the 56 km race was more than 21 times higher than that reported in this one study in 42 km (marathon) runners.[15] Besides the obvious longer race distance (56 km vs 42 km), other reasons

Table 5 Incidences of specific medical complications by organ system affected and by final diagnosis in all runners and all years

	All runners	
System	Incidence per 1000	95% CI
Cardiovascular	1.93	1.62 to 2.29
Serious cardiac		
All serious cardiac	0.12	0.06 to 0.24
Ischaemic heart disease	0.05	0.01 to 0.14
Arrhythmia	0.03	0.01 to 0.12
Myocarditis	0.05	0.01 to 0.14
Postural hypotension	1.75	1.45 to 2.10
Other cardiovascular	0.06	0.02 to 0.16
Musculoskeletal	1.31	1.06 to 1.61
Dermatological	1.37	1.11 to 1.68
Serious exercise-associated muscle cramps	0.91	0.71 to 1.17
Gastrointestinal	0.88	0.68 to 1.14
Respiratory	0.53	0.38 to 0.74
Asthma	0.18	0.10 to 0.32
Infection	0.21	0.13 to 0.36
Pulmonary oedema	0.03	0.01 to 0.12
Respiratory other	0.11	0.05 to 0.22
Fluid, electrolyte and acid–base	0.43	0.29 to 0.62
Hyponatraemia	0.23	0.14 to 0.38
Dehydration	0.18	0.10 to 0.32
Acidosis	0.02	0.00 to 0.11
Metabolic	0.24	0.15 to 0.40
Fatigue	0.26	0.16 to 0.42
CNS	0.14	0.07 to 0.26
Convulsions	0.02	0.00 to 0.11
Confusion	0.02	0.00 to 0.11
Other collapse	0.03	0.01 to 0.12
Concussion	0.05	0.01 to 0.14
CNS other	0.03	0.01 to 0.12
Temperature regulation	0.14	0.07 to 0.26
Hyperthermia	0.09	0.04 to 0.20
Hypothermia	0.05	0.01 to 0.14
Renal	0.05	0.01 to 0.14
Other	0.11	0.05 to 0.22

CNS, central nervous system.

for this finding are not clear. First, the definition of what constitutes a serious complication in the two studies is different and there may have been under-reporting. Although environmental conditions may explain differences in these two studies, we do note that there was a large variation in the environmental conditions in Roberts's study, whereas the annual variation in the WBGT indices during our 4-year study was minimal (variation between 13.5 and 16.5). The WBGT indices in the 4-year period were always in the 'low-risk' category.[25] We strongly suggest that race medical directors take note of this and encourage further research in this area.

There are however more data for some specific serious medical complications during marathon and ultramarathon running, such as hyponatraemia. In our study, the incidence of symptomatic hyponatraemia in 56 km runners was 0.23/1000. This incidence is lower compared to some studies (0.31[17]; 0.6[26]) and higher than that reported in other studies (0.05[27]; 0.001[19]). There is no obvious explanation for this wide discrepancy in the reported incidences of hyponatraemia. However, factors that may be related to these differences are (1) the definition of hyponatraemia (clinical vs biochemical), (2) different protocols for prerace runner education on fluid intake, (3) different environmental conditions, including heat stress, (4) different events and (5) differences in the availability of water stations on route. Further studies are needed to determine the precise incidence and risk factors for hyponatraemia in distance running.

In our study, we report an overall incidence of medical complications of 8.27 per 1000 runners (5.14 in 21 km runners; 12.98 in 56 km runners). This is lower when compared to the 18.9 per 1000 in 42 km (marathon) runners that have been reported in one other study.[15] As these are different races, the data may not be comparable. Furthermore, in the study by Roberts *et al*, all medical complications were documented, whereas we only reported medical complications that were of sufficient severity to require assessment by a medical doctor, and this could be another factor explaining the different incidences. We suggest that standardised definitions and procedures be developed to report medical complications data so that the results of future studies can be compared.

To the best of our knowledge, the profile of other less serious medical complications in marathon runners has only been reported in two studies.[15 16] In a 12-year period, the profile of medical injury and illness for the Twin Cities marathon was reported.[15] Exercise-associated collapse (59% of medical complications), skin complications (21%) and musculoskeletal complications accounted for the majority of less serious medical complications reported in that study. In our study, the most common complication was also exercise-associated collapse (postural hypotension; 21%), followed by dermatological complications (17%) and musculoskeletal complications (16%). sEAMC and gastrointestinal complications each accounted for 11% of all complications. Our data are therefore similar to that previously reported in marathon runners. Although we cannot strictly compare our data to the profile of medical complications reported in the multistaged ultramarathon race, we do note similarities with respect to dermatological and musculoskeletal complications being very common.[16]

To the best of our knowledge, the incidence of medical complications (per 1000 race starters) in 56 km ultramarathon runners compared to 21 km runners has not been studied. In our study, the overall incidence of medical complications (per 1000 runners starting the race) was significantly higher in the 56 km race (12.89) compared with the 21 km race (5.14). However, it is important to note that the incidence of serious medical complications was not significantly different in the 56 km race (0.65) compared to the 21 km race (0.51). This highlights that there are differences in the nature of medical complications between the races. In 56 km runners, the incidence of exercise-associated postural hypotension ($p<0.0001$), sEAMC ($p<0.0001$), gastrointestinal complications ($p<0.0001$), musculoskeletal complications ($p<0.0028$) and fatigue ($p<0.0022$) were significantly higher than in the 21 km runners. The most likely explanation for these observations is likely to be the difference in the overall duration of these races, but this would require further study. However, for the race organiser and the medical staff the practical clinical message is that a runner is more likely to develop any medical complication, and some specific medical complications during the longer 56 km compared with a 21 km race. It is also important to note that the risk factors for medical complications in 56 km races and 21 km races may be different, and these factors should be explored in future studies. We suggest that an analysis should be conducted to identify independent risk factors for medical complications associated with distance running, and that these

Table 6 Incidences of medical complications by organ system affected and by final diagnosis in 21 and 56 km runners

System and final diagnosis	21 km race Incidence	21 km race 95% CI	56 km race Incidence	56 km race 95% CI	p Value
Cardiovascular	1.21	0.92 to 1.61	3.00	2.40 to 3.74	<0.0001*
Serious cardiac					
All serious cardiac	0.13	0.05 to 0.30	0.11	0.04 to 0.35	1.0000
Ischaemic heart disease	0.05	0.01 to 0.20	0.04	0.01 to 0.27	1.0000
Arrhythmia	0.03	0.00 to 0.18	0.04	0.01 to 0.27	1.0000
Myocarditis	0.05	0.01 to 0.20	0.04	0.01 to 0.27	1.0000
Postural hypotension	1.06	0.79 to 1.44	2.77	2.20 to 3.48	<0.0001*
Other cardiovascular	0.03	0.00 to 0.18	0.11	0.04 to 0.35	0.3088
Musculoskeletal	0.96	0.70 to 1.32	1.82	1.37 to 2.42	0.0028*
Dermatological	1.29	0.98 to 1.70	1.48	1.08 to 2.03	0.5199
Serious exercise-associated muscle cramps	0.25	0.14 to 0.47	1.90	1.44 to 2.50	<0.0001*
Gastrointestinal	0.23	0.12 to 0.44	1.86	1.41 to 2.46	<0.0001*
Respiratory	0.35	0.21 to 0.60	0.80	0.52 to 1.22	0.0158*
Asthma	0.15	0.07 to 0.34	0.23	0.10 to 0.51	0.5602
Infection	0.13	0.05 to 0.30	0.34	0.18 to 0.66	0.0637
Pulmonary oedema	–	–	0.08	0.02 to 0.30	–
Respiratory other	0.08	0.02 to 0.24	0.15	0.06 to 0.40	0.4485
Fluid, electrolyte and acid–base	0.33	0.19 to 0.57	0.57	0.34 to 0.94	0.1430
Hyponatraemia	0.23	0.12 to 0.44	0.23	0.10 to 0.51	0.9992
Dehydration	0.10	0.04 to 0.27	0.30	0.15 to 0.61	0.0769
Acidosis	–	–	0.04	0.01 to 0.27	–
Metabolic	0.08	0.02 to 0.24	0.49	0.29 to 0.85	0.0008*
Fatigue	0.10	0.04 to 0.27	0.49	0.29 to 0.85	0.0022*
CNS	0.13	0.05 to 0.30	0.15	0.06 to 0.40	1.0000
Convulsions	0.03	0.00 to 0.18	–	–	–
Confusion	0.03	0.00 to 0.18	–	–	–
Other collapse	0.03	0.00 to 0.18	0.04	0.01 to 0.27	1.0000
Concussion	–	–	0.11	0.04 to 0.35	–
CNS other	0.05	0.01 to 0.20	–	–	–
Temperature regulation	0.15	0.07 to 0.34	0.11	0.04 to 0.35	0.7491
Hyperthermia	0.10	0.04 to 0.27	0.08	0.02 to 0.30	1.0000
Hypothermia	0.05	0.01 to 0.20	0.04	0.01 to 0.27	1.0000
Renal	–	–	0.11	0.04 to 0.35	–
Other	0.05	0.01 to 0.20	0.19	0.08 to 0.46	0.1243

*Indicates a significant difference between the 56 and 21 km race (p<0.05).
CNS, central nervous system.

analyses should be carried out separately in the 21 and 56 km races.

Finally, in our study, we showed that female runners and older runners are less likely to complete an endurance race (21 or 56 km). We are not aware of any other study where this has been reported, and the precise reason/s for not finishing the races is/are not clear and needs further study. We recognise that the development of medical complications during a race could be one possible reason for not finishing a race. Therefore, we suggest that the relationship between gender and age as potential risk factors associated with medical complications during 21 and 56 km running be explored in further studies.

This study has a number of strengths, and also some limitations. To the best of our knowledge, this is one of the largest prospective studies documenting not only deaths, but also serious life-threatening and other medical complications during endurance races. Other strengths of the study are that the medical data were comprehensive, and were collected by physicians using a standardised method of collection and classification. Precise definitions for what constitutes a medical complication and a serious medical complication were reported. Also, we collected data on medical complications that developed either during the race, or at completion of the race. Finally, we had not only accurate data on race starters (as most previous studies) but also had novel data on race finishers. One of the main limitations of our data relates to the small absolute number of deaths and the relatively small number of runners in the analysis of the mortality data. In comparison to other studies documenting sudden cardiac deaths in distance runners, our data on sudden death are therefore limited and should be interpreted with caution. However, our data on serious life-threatening medical complications are very accurate and this has not been reported in studies on sudden cardiac deaths in runners. We aim to continue our surveillance of deaths and medical complications in these races over the next few years.

Summary and conclusions

In our study, sudden cardiac death and serious medical complications are higher in 21 km runners while the incidence of overall medical complications is higher in 56 km runners. The most common medical complications are postural hypotension, followed by dermatological and musculoskeletal complications but the incidence of these complications differs in 21 km compared with 56 km runners. In order to reduce the risk of medical complications during distance running, the next step is to determine the risk factors for any medical complications and specific complications during distance running. Thereafter, strategies to reduce the risk of these adverse medical events in endurance runners can be implemented and then re-assessed.

What are the new findings?

- The incidence of sudden death was very high during 21 km running (1 in 20 000 race starters).
- The risk of serious life-threatening medical complications during running was similar in 21 km (1 in 1961 race starters) and 56 km (1 in 1538 race starters) runners.
- In general, medical complications during a race were more common in 56 km runners (1 in 77 race starters) compared with 21 km runners (1 in 195 race starters).
- Postural hypotension, dermatological complications, musculoskeletal complications, serious exercise-associated muscle cramping and gastrointestinal complications were the more common specific medical complications during distance running.
- The types of medical complications during distance running were different in 21 km compared with 56 km runners.

How might it impact on clinical practice in the near future?

- To the best of our knowledge, the SAFER I (*S*trategies to reduce *A*dverse medical events *F*or the *E*xercise*R*) study is the largest prospective cohort study accurately documenting the incidence and nature of medical complications during 21 and 56 km distance running.
- Twenty-one kilometre runners are a particularly high risk group for sudden death and these runners should be targeted in prevention programmes.
- The data on serious and other medical complications will be of immediate clinical value to race medical directors to assist them in planning medical care at races, particularly as it relates to staff compliment (number and skill sets of staff), medical facilities and prerace advice to runners.
- These data also form the basis for further clinical studies to determine risk factors for medical complications, and this will assist in planning preventative programmes to reduce the risk of adverse medical events in the exercising individual.

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Competing interests None.

Ethics approval For purposes of conducting research on this population, this registry of runners has been approved by the Research Ethics Committee of the University of Cape Town (REC R030/2013) and specific permission to investigate the incidence and nature of medical complications during endurance running in the Two Oceans races was obtained from the Research Ethics Committee of the University of Cape Town (REC 009/2011).

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