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Mortality during marathons: a narrative review of the literature

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ABSTRACT

Background Millions of community-dwelling individuals run marathons each year. There are infrequent deaths, which are often reported widely, and may create unnecessary alarm about the potential risks. Equally, sensible planning for such eventualities is important when staging an event.

Objective The aim of the review was to determine the risk of death from running a marathon and the likely location of such deaths in order to inform the public of the likely risks and improve planning for such events.

Design Narrative review.

Data sources Primary: PubMed. Secondary: contact was made with the organisers and medical teams of specific marathons and online data sought where necessary.

Eligibility criteria for selecting studies Studies had to report the number of participants and deaths during, or within 24 hours of completing the marathon. Results relevant to half marathons or ultramarathons or other endurance events, such as triathlons, were not included. Deaths due to terrorist activity were not included.

Results The risk of death estimated by these studies was approximately 0.67 per 100 000 finishers, that is, 1 death per 149 968 participants. From those studies that reported deaths by sex, the rate of male deaths was 0.98/100 000 (1 per 102 503) vs 0.41/100 000 (1 per 243 879) in females. Deaths tended to occur in the last quarter of the race.

Summary/conclusion The risk of death from participating in a marathon is small. Men are more at risk than women. Deaths tend to occur later in the race.

What is already known?

- It is recognised that participating in a marathon is associated with a risk of death.
- Marathon participants tend to die later in the race and women appear to be at less risk than men.

What are the new findings?

- The risk of death was estimated to be 0.67 per 100 000 finishers, that is, 1 death per 149 968 participants.
- Deaths tended to occur in the last quarter of the race. From those studies that reported deaths by sex, the rate of male deaths was 0.98/100 000 (1 per 102 503) vs 0.41/100 000 (1 per 243 879) in females.

INTRODUCTION

It has long been recognised that during endurance events, such as marathons, fatalities may occur. These events are fortunately rare, but when they occur, often make front page headlines, for example, the death of a young man at the 2018 London Marathon.[1]

As a consequence of the availability heuristic,[2] a widely known cognitive bias, the true risks of participation may be overestimated by both participants and doctors, and act as a potential barrier to marathon participation.

Therefore, it is important for the general public and for doctors who may have to advise patients whether or not to participate, about the likely risks of harm. It is also important for doctors to understand which conditions in particular should be sought prior to participation. Finally, it is important for race organisers and their associated medical teams to understand the frequency of such events, as well as the likely emergencies that they may have to deal with and where such events are most likely to occur.

The purpose of this paper is to draw together the current literature that has been published to quantify the risk of dying during a marathon and the reasons why, whether there is any difference between the sexes, and at what stage of the marathon most fatalities occur, to assist with advising participants and planning medical cover.

METHODS

A search using the term 'Marathon' and 'Death' or 'Mortality' on PubMed was performed on 15 March 2018. Only English language publications were included. Results relevant to half marathons or ultramarathons or other endurance events, such as triathlons, were not included, except where it was impossible to separate certain results, as detailed in the text. Deaths due to trauma have not been included.

Data, including the number of participants, deaths, the age and sex of those who died and location on the cause of such deaths,

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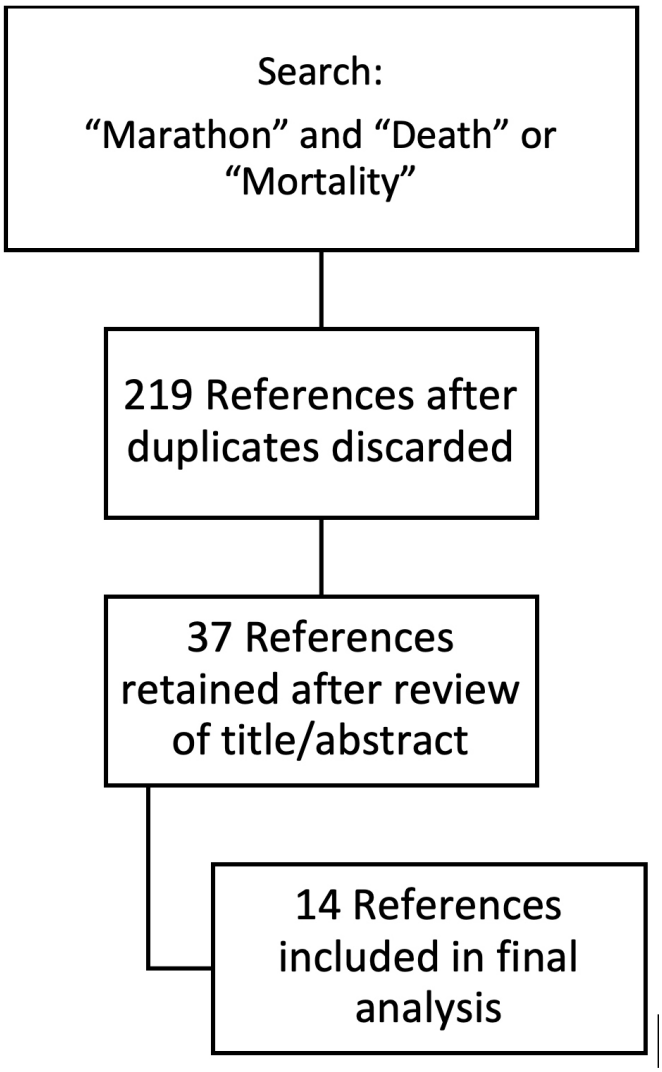


Figure 1 Search strategy and outcomes.

as well as the cause of death, were abstracted from the papers. Online searches and direct approaches of event organisers were used to confirm the accuracy of data and supplement published information where necessary.

These results were combined to estimate the risk of death from participating in a marathon.

RESULTS

The search strategy yielded 219 references after duplicates were removed. The titles and abstracts of those articles were reviewed and 182 were discarded. The full texts of the 37 remaining articles were obtained. An ancestry and citation search[3] of those articles was performed to ensure no articles had been missed and 14 articles were included in the final analysis (figure 1).

It became clear that there were two categories of papers. The first category comprised papers that examined total marathon participation and associated mortality in countries over a period of time. The second category comprised a number of papers that focused on specific marathons, including the Boston and London Marathons.

American marathons

There have been a number of efforts to collect data from a larger number of marathons that have been staged across America with specific searches of news outlets and approaches to medical teams to endeavour to collect all of the fatalities associated with races. It is probable that the data from these papers overlap.

Redelmeier and Greenwald (2007)

Redelmeier and Greenwald[4] published an analysis of 26 marathons and their related deaths, staged in the USA, which they followed for up to 30 years in 2007. The principal focus of the paper was to compare the number of marathon deaths with the expected number of motor vehicle fatalities to determine whether running a marathon was safer than not running one.

The authors screened the 328 American marathons listed in *Runner's World* on 1 January 2005. They excluded those with less than 20 years of data, fewer than 1000 participants annually, or those that were located primarily on off-road trails or that were part of triathlons or other combined endurance events. They selected 26 marathons randomly from the remainder. Note that the Marine Corps Marathon (MCM) data (presented in more detail subsequently) are included in this analysis. Data on 'sudden cardiac deaths' were obtained from local newspapers on the days after each marathon. Race directors were contacted.

A total of 3 292 268 participants were included in the analysis. There were 26 sudden cardiac deaths. Fifteen marathons had no deaths, six had one death and five (Boston, New York, Chicago, Honolulu and the MCM) had more than one; New York reported two deaths in 1994.

The average age of the fatalities was 41 years. Eighty-one per cent (21) of those who died were men. Five deaths occurred in people who had completed a marathon before. There were autopsy results on 24; 21 had coronary artery disease. Coronary anomalies were noted in two. Electrolyte abnormalities were thought to be significant in four and heat stroke in one. Most died within a mile of the finish line (online supplementary appendix figure 1). The overall risk of a fatality, as estimated by this paper, was 0.79/100 000 or 1 death for every 126 626 finishers.

Mathews *et al* (2012)

Using publicly available racing (MarathonGuide.com, Athlinks, and The Association of Road Racing Statisticians) and news (Google, LexisNexis) databases, and by directly contacting race organisers, the authors[5] collected statistics on marathon finishers and deaths between 2000 and 2009.

The denominator—the numbers completing marathons during the 10-year period—was 3 718 336. There were 2 255 060 men who completed a marathon and 1 463 276 women. They identified 28 people (22 men, 6 women) who died during the race or within 24 hours

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of finishing. The male death rate was 0.98/100 000 and the female death rate was 0.41/100 000. The overall death rate was 0.75/100 000 or 1 death for every 132 798 finishers.

The median age of death was 41.5 years (IQR 25.5, range 22–68). Fourteen deaths occurred in people over the age of 45. Thirteen of those deaths were caused by atherosclerosis (online supplementary appendix table 1). In younger racers, none of the deaths were caused by cardiovascular disease. The median distance travelled before dying was 22.5 miles (IQR 10.6). Seven completed the marathon before dying. Eighteen deaths occurred after mile 20. Cardiac and cardiovascular aetiologies accounted for 24/28 deaths. People were most likely to die in October marathons (n=11); 27% of marathon participants raced in October.

Kim *et al* (2012)

In 2012, a study by Kim *et al*[6] looked at cardiac arrests that occurred while running or within an hour of running a marathon or half marathon.

The database of cardiac arrests was compiled prospectively from 1 January 2000 to 31 May 2010—a time period slightly different from the Mathews *et al*'s study. The arrests were cross-referenced using LexisNexis and Google. Further searches were performed directed at particular race events and their local newspapers. Contact was also made with race officials. Cases of cardiac arrest were retained for the final analysis if they were identified in three separate data sources or confirmed with race staff. The next of kin of those who died were written to asking for further data about exercise history and family history and asking for consent to access medical data. *Running USA* compiled the statistics for participation (not finishers) rates in marathons or half marathons in the USA.

It was estimated that 3 949 000 people participated in a marathon, and 6 922 000 participated in a half marathon. Fifty-nine cardiac arrests were identified, 40 in marathons and 19 in half marathons. The incidence of cardiac arrest was 1.01/100 000 in marathons. Fifty-one of the 59 people who arrested were male. Thirty-four of the 40 arrests in marathons were in men. Male marathon participants had a rate of cardiac arrest of 1.41/100 000. The mean age of those who arrested was 42±13 years. Forty-two of the 59 died.

The mean age of those who died was 39±9 years. The death rate was 0.63/100 000 during marathons (n=25) and 0.25/100 000 (n=17) during half marathons. Overall, men were more likely to die than women (0.62/100 000 vs 0.14/100 000) during marathons and half marathons. Most arrests occurred in the latter quartile of the race (online supplementary appendix figure 2). The data were not separated by race type or by mortality. Hypertrophic cardiomyopathy (HCM) was the most common underlying diagnosis overall. In those who survived, coronary disease was more common.

Webner *et al* (2012)

In 2009, this group sent 33 item surveys to 400 race directors of US marathons to ask about the number of marathon participants and associated deaths. Eighty-eight (22%) returned the surveys. The marathons were run between 1976 and 2009.[7]

There were a total of 1 710 052 runners. Races had between 30 and 30 000 participants. Thirty arrests and 10 deaths were reported. The risk of death was therefore 1 in 171 005 participants, or 0.58/100 000. The cause of death was coronary artery disease in seven. One person had an anomalous coronary artery. The cause of death was not established in two cases. Twenty-eight of the 30 runners who arrested were male. The mean age of those who arrested was 49.7 years. The mean age and sex distribution of those who died were not specified in the paper.

The location of the arrests was again skewed towards the final miles of the marathon (online supplementary appendix figure 3), with the majority of cardiac arrests occurring between mile 23 and the finish.

Swedish marathons

Nilson and Börjesson presented data on all marathons run in Sweden and their associated deaths between 2007 and 2016.[8] It was estimated that there were 479 221 marathon runners during that period of time. No fatalities were reported. Two deaths were reported in races between 21 and 42 km; 677 050 runners of races of these distances were recorded (online supplementary appendix table 2).

Summary of country-wide survey marathon data

These papers can be brought together. The available data suggest that the typical person who arrests is a male around 40 years old. The cause of death is often considered to be coronary artery disease. Typically, cardiac arrest and death occur in the last quartile of the race.

The risk of death estimated by these studies was approximately 0.67 per 100 000 finishers, that is, 1 death per 149 968 participants (table 1).

Of the two studies that reported marathon deaths by sex, that is, Redelmeier and Greenwald and Mathews *et al*, there were 43 males (80%) who died and 11 females (20%). Mathews *et al* reported the breakdown of participants by sex in addition. In that study there were 22 men who died and six women. The rate of male deaths was 0.98/100 000 (1 per 102 503) vs 0.41/100 000 (1 per 243 879) in females (table 2).

Specific marathons

A number of papers have looked in more detail at specific marathons. These have typically been compiled by teams closely involved with the organisation of such marathons.

The MCM and the Twin Cities Marathons

Three papers have been published by the medical team associated with two marathons in the USA: the MCM held in Washington, DC, and the Twin Cities Marathon (TCM) held in Minneapolis.

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Table 1 Risk of death during marathons—country-wide studies

Author	Participants	Country	Deaths	Median age	Mean age	Deaths per 100 000	1 Death per
Redelmeier and Greenwald[4]	3 292 268	USA	26		41	0.79	126 626
Mathews *et al*[5]	3 718 336	USA	28	41.5		0.75	132 798
Kim *et al*[6]	3 949 000	USA	25			0.63	158 730
Webner *et al*[7]	1 710 512	USA	10			0.58	171 005
Nilson and Börjesson[8]	479 221	Sweden	0			0.00	–
Total	13 347 166		89	41.5	41	0.67	149 968

Maron *et al* (1996)

This paper focused on the MCM from 1976 to 1994 and the TCM from 1982 to 1994. All deaths were included.[9] The data are reproduced in online supplementary appendix table 3.

A total of 215 413 runners successfully completed the marathons during this time. Four sudden deaths occurred during (n=3) or shortly after (15 min, n=1) completion of the marathon (3 male, 1 female). The three men had coronary disease and the one woman had an anomalous coronary artery. The one woman died in 1990 in the MCM, aged 19. One man died in the TCM in 1989, aged 40. Two men died in 1986 and 1993 in the MCM, aged 32 and 58, respectively. This yields a death rate of 1.86/100 000 participants, or 1 death for every 53 853 participants.

Roberts (2000)

This paper looked at the 81 277 entrants in the TCM from 1982 to 1994. It therefore contains no new information over and above that of Maron *et al*[9] with regard to deaths.[10]

Its focus was describing all medical issues experienced by marathon runners. For interest, medical encounter rates were 25.3/1000.

Of note, it was stated that 60 757 finished the course—slightly different from 60 379 from the 1996 paper. There were 48 330 male finishers and 12 427 females. There appears to be a further typographical error in the text, and this number is derived from the table reproduced (online supplementary appendix table 4).

Combining the data from Maron *et al*[9] and Roberts[10] gives a slightly different estimate of mortality—that is, 4 deaths and 215 791 finishers, or 1.85 deaths per 100 000 finishers or 1 death per 54 948 finishers (online supplementary appendix table 5).

Roberts *et al* (2013)

This paper used data from the two marathons between 1982 and 2009. 1982 was chosen, as data were reported by sex from that year onwards.[11]

The paper reported that there were 540 892 finishers during the study period; 379 863 were male and 168 227 were female.

In total 14 runners collapsed suddenly. Seven were successfully resuscitated. There were seven sudden cardiac deaths. There was still only one female fatality (age 19, anomalous coronary artery, 1990, MCM). The rest who died were male. The underlying diagnosis for all men was coronary artery disease. The mean age of the men was 48 years. The location of the collapse was on average at 16 miles.

The rate of death overall was 1/78 299 finishers or 1.28/100 000. In men, the rate was 1/63 311 finishers (1.58/100 000) whereas in women it was lower at 1/68 227 (0.59/100 000).

Details of the deaths can be found in online supplementary appendix table 6 but were principally due to coronary artery disease.

Further data

The MCM has now published data on their website of the number of finishers since the race began in 1976. It can be found at www.marinemarathon.com and this is reproduced in online supplementary appendix table 7.

This allows for a combination of all of the papers and data, leading to a final estimate of risk for these two

Table 2 Risk of death during marathons by sex—country-wide studies

Author	Males	Females	Male deaths	Female deaths	Male deaths per 100 000	1 Death per (male)	Female deaths per 100 000	1 Death per (female)
Redelmeier and Greenwald[4]			21	5				
Mathews *et al*[5]	2 255 060	1 463 276	22	6	0.98	102 503	0.41	243 879

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marathons. Between 1982 and 2009, there were 540 892 finishers. From 1976 to 1981, a further 26 387 completed the MCM. The total finishers of the two races from their inception (MCM 1976, TCM 1982) to 2009 were therefore 567 279. There were seven deaths in that time; six were male and one was female. The rate of death, therefore, was 1.23/100 000 finishers, or 1 death for every 81 039 finishers.

The London Marathon

Dan Tunstall-Pedoe was the London Marathon Medical Director between 1981 and 2006. He presented data on the first 26 London Marathons in 2007.[12] Data were obtained from St John's ambulance, receiving hospitals and the coroner. The paper stated that there were a total of 650 000 finishers. A total of eight deaths were recorded in this time. The first death was in 1990 and ascribed to HCM. In 2001 and 2005, there were two further deaths from HCM. Deaths in 1993, 1995, 1996, 1997 and 2003 were ascribed to ischaemic heart disease (IHD). This yielded a crude rate of death of 1/81 250 (1.23/100 000).

There are also corroborative data online, published by Tunstall-Pedoe at Peak Performance with data up to and including 2003. The data there are slightly different. HCM deaths were reported as occurring in 1990 and 2001—as above. Five deaths from IHD were reported as occurring in 1991, 1994, 1995, 1997 and 2003. This was the same number of deaths as in the published paper over the same time frame. Data were published on the number of finishers up until 2003. This yielded a death rate of 1/67 414 (1.48/100 000).

An online search to determine the number of finishers yielded data from additional sites. There are race reports, hosted on the London Marathon website, which mention the number of finishers in the very early races. Wikipedia provides data on the first London Marathon. MarathonGuide.com has data on the number of London Marathon finishers (http://www.marathonguide.com/results/browse.cfm?MIDD=16150426). Combining the data from these sources yields the online supplementary appendix table 9. All the data are from the MarathonGuide.com unless otherwise specified.

Professor Sanjay Sharma is the current director of the London Marathon. He stated (personal communication) that there have been 15 deaths. As of 2018, over 1 000 000 people had completed the London Marathon (1 078 988). This yields a death rate of 1/71 933 or 1.39/100 000. online supplementary appendix table 8 summarises the data as far as possible.

The Boston Marathon

Data for the Boston Marathon come from a number of sources, and much information can be found online (http://www.wikiwand.com/en/Boston_Marathon, https://en.wikipedia.org/wiki/List_of_marathon_fatalities, https://en.wikipedia.org/wiki/Boston_Marathon). Deaths not due to trauma have been referred to in academic papers. In 2002, there was a death from hyponatraemia. The woman died at mile 22 at the age of 28.[13] In 1996, a 61-year-old man died at the finish from IHD.[14] Finally, in 1973, a 44-year-old man had an anterior myocardial infarction at mile 24 and died.[14] No papers have been published since 2012.

Data on the number of participants can be found on https://www.johnhancockmarathonhub.com/history-and-past-results/participation/. Between 1897 and 2011, there have been 496 942 entrants (online supplementary appendix table 9). We are grateful to Jack Fleming of the Boston Athletic Association for directing me to the site.

The rate of death can therefore be calculated at 0.60/100 000 entrants or 1 per 165 647.

Between 1897 and 2011, a total of 352 185 men and 144 700 women entered the race. The rate of death for men is therefore 0.57/100 000 (1 per 176 093) and for women is 0.69/100 000 (1 per 144 700).

The Paris Marathon, 2007–2011

Gerardin *et al* have presented data from 2007 to 2011.[15] During this time period, 153 071 people entered the marathon, and approximately 148 006 completed it. Approximately 25 846 (17.5%) were female and 122 160 were male. There were no fatalities during this period (online supplementary appendix table 10).

The Hong Kong Marathon, 2001–2009

Fong and Wai have published data on the Hong Kong Marathon between 2001 and 2009.[16] During this time, there were 41 502 entrants, but one fatality, in 2006 (supplementary appendix table 11). A 53-year-old man developed breathing difficulties; the final cause of death was considered to be asthma.

The Vancouver Marathon, 2006–2011

Turris *et al* have presented data from the Vancouver International Marathon between 2006 and 2011.[17] During this time, there were a total of 67 402 entrants, and no deaths (supplementary appendix table 12).

Summary

These sets of data can be drawn together, yielding a death rate of 1/96 207 finishers or 1.04 deaths/100 000 finishers (table 3). The rates of death are higher than those ascertained by more general surveys, as would be predicted as the authors were directly linked with providing medical support to the marathons over many years. Unfortunately, there are no data to compare fatalities by sex or location in the marathon.

DISCUSSION

Different methodologies have yielded conflicting estimates of the death rates during marathons. Large surveys of multiple marathons have suggested that the death rate is just under 0.70/100 000 finishers (0.67). Detailed studies of a small number of events have suggested the rate is higher at just over 1.00/100 000 finishers (1.04), although it should be noted that the death rate was higher in the three best studied marathons—the London

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Table 3 Mortality during specific marathons

Specific marathons	Years	Finishers/entrants	Deaths	Deaths per 100 000	1 Death per
MCM+TCM	1976–2009	567 279	7	1.23	81 040
London Marathon	1981–2018	1 078 988	15	1.39	71 933
Boston	1897–2011	496 942	3	0.60	165 647
Vancouver	2006–2011	67 402	0	0.00	–
Hong Kong	2001–2009	41 502	0	0.00	–
Paris	2007–2011	153 071	0	0.00	–
Total		2 405 184	25	1.04	96 207

MCM, Marine Corps Marathon; TCM, Twin Cities Marathon.

Marathon and the MCM and TCM. The MCM has the highest reported rate of death at 1.94/100 000 finishers. In contrast, in 12 years in Japan, a nation with a rich running tradition, recently it was reported that there have been no deaths at the marathon distance, but the precise number of runners was not included, precluding its inclusion in this analysis.[18] Women appear to be at lower risk than men, and most fatalities occur in the final miles of the race. What is clear from this analysis is that the chances of dying during a marathon are very low.

It is not surprising that the death rates are slightly higher in reports of specific marathons, where the reports have been produced by the team directly responsible for healthcare for these events. They will be aware of all the medical problems faced, and it is almost inconceivable that a death would be missed. The larger studies of multiple events have relied on direct contact with race organisers, with incomplete responses and searches of relevant press reports. Although deaths in high-profile events are now widely reported, this is not always the case for smaller events. Furthermore, it is more likely that deaths will be missed compared with the studies which have focused on specific marathons, and therefore these papers have the potential to underestimate the true fatality rate. One potential solution to help understand the problem in more detail would be to create a centralised database with voluntary reporting of deaths, although it would require funding and oversight. Depending on its construction it could yield more precise information about the numbers and aetiologies of deaths.

Looking at the causes of death is important for marathon organisers. The most common cause of death that was reported was IHD, which predominantly affected men over 40. Other cardiac causes of death included HCM and anomalous coronary arteries. It is unknown how many had antecedent symptoms, but training programmes typically do not put runners under the same sort of stress as they will experience on marathon race day, with most 'long runs' peaking at 20 miles and at a slower pace. The stress of the marathon releases a number of inflammatory biomarkers and there is also evidence of hypercoagulability, creating a situation in which plaque rupture and subsequent coronary thrombosis is more likely.[19] Interestingly, it has been recognised recently that strenuous exercise is associated with more prevalent coronary artery calcification, but this is not associated with increased mortality.[20] Some have argued that aspirin should be considered in those likely to be at higher risk of myocardial infarction.[21]

How to screen for cardiac problems in advance? An ECG can be helpful and is often advised but does not reliably pick up either IHD or HCM. An echocardiogram can diagnose HCM reliably. A cardiac CT can pick up asymptomatic coronary disease or anomalous coronary arteries. Judging from the lack of symptoms during training an exercise test or stress echocardiogram may be falsely reassuring.

Hyponatraemia is a more common cause of death in younger marathon participants. A degree of hyponatraemia is common in marathon runners.[13] Its aetiology is probably more complex than might be assumed, although the principal cause is drinking to excess.[22] The consensus advice is that marathon runners should 'drink to thirst.'[23] Sodium supplementation remains controversial.[24]

Heatstroke is a concern to marathon organisers but appears to be a relatively rare cause of death (see online supplementary appendix tables 1 and 8). Some people appear more susceptible than others. Recommendations to prevent heat-related illness include avoiding participation if there has been a recent fever, drinking appropriately and organisers can provide facilities for cooling athletes; run-through showers, for example, are common.[25]

The observation that most deaths occurred in the latter stages of the races is important for race organisers. There are always finite resources and choosing where to deploy medical staff is an important consideration. An analysis of the data suggests that resuscitation facilities should be concentrated towards the end of the race, although clearly cover needs to be available along the entire course.

There are a number of limitations to this study. First, as already mentioned, the methodology of many of the studies may not have captured all deaths, particularly those studies where the investigators were not

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intimately involved with the marathon and relied on surveys and scanning newspaper and other sources of information. Therefore, the true death rate from marathon running may be higher. A limitation of all studies was that participants may have run multiple marathons, and therefore the total number of unique participants would likely have been lower, raising the individual risk further.

Second, in many situations the cause of death was not available, and therefore causes such as heatstroke may be of greater concern than realised. Finally, there were no data on the medical history of patients, or any symptoms experienced prior to participation. Such information may reveal symptoms or signs that could help reduce the risk of death further.

In conclusion, running marathons is generally safe for the overwhelming majority of participants, but fatalities will occur, principally towards the end of an event. Comprehensive testing of athletes would be required to significantly reduce the number of events, and this may not be cost-effective, or desirable. Other measures, such as the correct stationing of resuscitation facilities, prophylactic aspirin for older male competitors, showers and suitably hydration advice may be more effective, but this remains to be proven.

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