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RESEARCH

Competing risks of mortality with marathons: retrospective analysis

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ABSTRACT

Objective To determine from a societal perspective the risk of sudden cardiac death associated with running in an organised marathon compared with the risk of dying from a motor vehicle crash that might otherwise have taken place if the roads had not been closed.

Design Population based retrospective analysis with linked ecological comparisons of sudden death.

Setting Marathons with at least 1000 participants that had two decades of history and were on public roads in the United States, 1975-2004.

Main outcome measures Sudden death attributed to cardiac causes or to motor vehicle trauma.

Results The marathons provided results for 3 292 268 runners on 750 separate days encompassing about 14 million hours of exercise. There were 26 sudden cardiac deaths observed, equivalent to a rate of 0.8 per 100 000 participants (95% confidence interval 0.5 to 1.1). Because of road closure, an estimated 46 motor vehicle fatalities were prevented, equivalent to a relative risk reduction of 35% (95% confidence interval 17% to 49%). The net reduction in sudden death during marathons amounted to a ratio of about 1.8 crash deaths saved for each case of sudden cardiac death observed (95% confidence interval: 0.7 to 3.8). The net reduction in total deaths could not be explained by re-routing traffic to other regions or days and was consistent across different parts of the country, decades of the century, seasons of the year, days of the week, degree of competition, and course difficulty.

Conclusion Organised marathons are not associated with an increase in sudden deaths from a societal perspective, contrary to anecdotal impressions fostered by news media.

INTRODUCTION

Physicians often recommend the health benefits of exercise, and millions of people take part on a regular basis, yet the outcome for a few participants is sudden death. These fatalities are typically diagnosed as "sudden cardiac death" and research has found no ideal method for predicting such events as even people without symptoms can be susceptible.[1-3] The deaths are poignant because the risk is voluntary, the outcome is catastrophic, and the person might otherwise have lived a long life.[4-6] The deaths also attract repetitive media attention, such as the high publicity given to deaths that occur in marathon runners.[7-11] As a consequence, the deaths undercut support for such community events, invite more screening of potential participants, and decrease public enthusiasm for aerobic exercise.[12-17]

Motor vehicle crashes are also hard to predict and are potentially fatal. In the United States, for example, 42 643 individuals died in motor vehicle crashes over the 6 354 190 km of public roads during 2003 (equal to about 12 deaths per 42 km (26.2 miles, the length of a marathon) of road per 1000 hours).[18] In contrast with sporting event fatalities, these deaths occur more than a hundred times each day and tend to be under-reported in the media.[19 20] The death statistics, furthermore, understate the full extent of consequences given the additional number of crashes that cause permanent disability. Ironically, deaths from motor vehicle crashes often lead to little public outcry or alterations in the behaviour of individuals in the community.[21] This competing risk of harm is rarely considered in the analysis of events related to exercise.[22]

No previous study has explored the extent to which marathons might actually decrease mortality. Our core theory was that the number of deaths attributed to running a marathon might be smaller than the number of deaths averted by the reductions in road crashes that would otherwise have occurred. We anticipated that such net benefits would be confined to the marathon route and would not be evident elsewhere in the state. To test this theory we examined marathons throughout the US for a population based test of whether the total number of sudden deaths (cardiac or crash related) changed when roads are closed to traffic and opened to marathon running from the perspective of society.

METHODS

Marathon identification

We screened the 328 marathons listed in the Runner's World registry on 1 January 2005 (chosen because the source is a leading publication in the field, is updated continually, and undergoes extensive public scrutiny). We randomly selected 26 marathons to provide a diverse national sample and followed each for up to 30 years. All included marathons were in the US and provided background material on their history. We excluded marathons with fewer than 20 years of

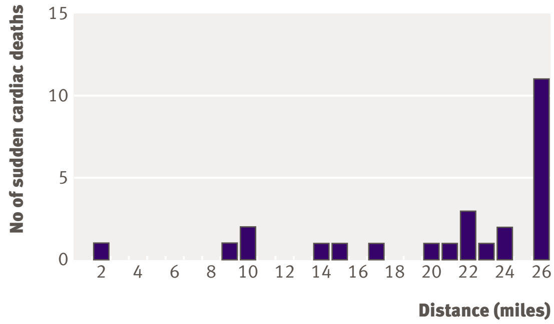

Fig 1 Distribution of sudden cardiac deaths according to distance along marathon course when participant collapsed (to nearest mile; 1 mile=1.6 km; total course 26.2 miles, equal to 42 km). Deaths expressed as counts summed over all marathons and years

experience or fewer than 1000 participants annually to ensure sufficient data for statistical testing of infrequent events. We also excluded marathons located primarily on off-road trails or that were part of a larger endurance event (for example, Ironman). Dates and routes of specific marathons were obtained from dedicated websites, regional periodicals, selected race directors, running clubs, local sportscasters, and national running organisations.

Cardiac fatalities

We obtained data on sudden cardiac deaths from local newspapers on the days after each marathon. Such fatalities are dramatic in nature, occur in public view, and are of intense interest in the press. For the Boston marathon, the sources were the *Boston Globe* and the *Boston Herald*. Similarly, reports for other marathons were obtained by identifying the newspaper with the widest local circulation and selecting the three issues published after the event. In cases where local newspapers provided no mention of the marathon, we searched other newspapers and periodicals for three issues until we found a review. Data on specific cause of death required up to four months of follow-up. Searches for missing data were validated by contact with race directors or local news media. We did not study suicide or violent crime because we had no compelling basis for an association between these causes of sudden death and a local marathon.

Crash fatalities

We retrieved road safety information for the US from the National Highway Traffic Safety Administration (NHTSA). This provided population based data for all fatal crashes on public roads starting from 1975 and continuing uninterrupted with a one to two year lag in reporting. As in past research,[23] we identified each person who died in a fatal crash and compared the number observed during a marathon with the number expected based on the same day one week before and one week after. This technique controlled for season of the year, day of the week, and year of the century and indirectly controlled for confounders such as vehicle technology, roadway layout, safety equipment, and drivers' skill. In all analyses we distinguished counties in the state that were inside and outside the marathon course and hours that were inside and outside the general interval of related road closures. The same locations and clock times were used for all comparisons to ensure identical intervals for all analyses.

National analyses

We compiled all marathons together into a central database taking into account the day of each marathon, along with the counties and state in which it was run. The location of each marathon was characterised according to state counties because the NHTSA database did not code crash location beyond this degree of precision. The time of each marathon was defined according to the approximate interval of road preparation, closure, clean up, and congestion as 3 am to 3 pm because archival data on exact times were unavailable in early eras for most marathons. The size of each marathon was estimated from the number of finishers in each year and course, with missing reports estimated by interpolation where possible or by replacement with zero otherwise (so that estimates of cardiac risk were biased upwards). Information on record times and cash prizes was obtained directly from the individual organisations based on the most recent data available.

Statistical analysis

Our primary analysis identified the number of motor vehicle deaths during each marathon compared with the number during the same hours one week before and one week after for the counties involving the marathon route (for example, a Sunday marathon in Chicago was compared with the Sunday before and the Sunday after in Chicago). Summary statistics were based on binomial tests and not adjusted for clustering.[24] The same comparisons were then replicated for state counties that were outside the marathon route to check for spillover in traffic flow to surrounding regions. Secondary analyses also checked for spillover in traffic flow by examining the days immediately before and after each marathon for counties inside the marathon route. Analyses of cardiac deaths during each marathon were expressed with exact confidence intervals and assumed that no cardiac deaths would have occurred otherwise (to ensure that estimates of cardiac risk were not biased downwards). Power calculations were not conducted. Further details are available directly from the authors.

RESULTS

The 26 marathons over the 30 years provided results for 2250 separate days of observation (750 marathon days and 1500 control days). Collectively, this amounted to 3 292 268 participants each running 42 km (26.2 miles). Over the 30 years there were 26 sudden cardiac deaths. Fifteen marathons had no deaths, six had one, and five had more than one (Boston, New York, Chicago, Honolulu, Washington

Marine Corps). One marathon had more than one death in a single year (New York with two deaths in 1994). No major trend in cardiac deaths was observed over the years.

The typical participant with sudden cardiac death was a middle aged adult man (average age 41 years, 81% men). Five deaths occurred in individuals who had previously completed a marathon. Autopsy results were available for 24, the most common finding being coronary atherosclerosis (n=21). Other contributing factors in scattered cases included electrolyte abnormalities (n=4), coronary anomalies (n=2), and heat stroke (n=1). The most common course location of cardiac death was at or within 1.6 km (1 mile) of the finish line (fig 1).

The overall risk of sudden cardiac death was equal to 0.8 per 100 000 participants (95% confidence interval 0.5 to 1.1). This was equivalent to about three deaths per 42 km of roadway per 1000 hours. No individual marathon course had an observed risk of sudden cardiac death that was significantly higher or lower than this baseline risk. The risk of sudden cardiac death was collectively distributed over about 86 million total miles of running by participants and mathematically equal to about two deaths per million hours of exercise.

Over the 30 years a total of 12 364 motor vehicle fatalities occurred on the 750 marathon days and 1500 control days in the corresponding states. A minority (n=930) were in counties inside the course whereas most (n=11 434) were in counties outside the course. The typical person who died in a fatal crash was a middle aged adult man (mean age 38 years, 78% men). About 56% were drivers, 25% were passengers, and 19% were pedestrians or other vulnerable road users. Marathon courses varied markedly around the prevailing average with no systematic week to week trend in crash deaths.

A total of 85 individuals died in fatal crashes on the marathon days in counties inside the course during hours when roads were closed. In contrast, 262 individuals died in fatal crashes on the control days in the corresponding counties and hours. Given that each marathon was paired with two control days, the discrepancy between observed and expected crash deaths on marathon days corresponded to a 35% relative decrease in risk (17% to 49%). This discrepancy was equal to an absolute decrease of 46 total crash deaths over the study ($P<0.001$).

We observed no major spillover in crash deaths to surrounding regions attributable to re-routing of traffic. Analysis of counties outside the course that compared observed with expected crash deaths during hours of road closure showed no countervailing increase in fatal crashes (relative decrease 0%, −6% to 7%). This discrepancy was equal to an absolute decrease of five deaths ($P>0.20$). Inspection of scatter plots showed no major departures from the general pattern of decreased crash deaths inside the marathon course and no increase in crash deaths outside the marathon course (fig 2).

Secondary analyses also showed no spillover in crash deaths to days surrounding the marathon for the counties involved in the road closures. Focusing on the three days before the marathon during the corresponding hours, we observed no significant increase in risk (relative increase in deaths 3%, absolute increase in deaths 9, $P>0.20$). Focusing on the three days after the marathon during the corresponding hours, we observed no significant increase in risk (relative decrease in deaths 4%, absolute decrease in deaths 11, $P>0.20$).

The ratio of crash deaths prevented was about 1.8 for each case of sudden cardiac death attributed to the marathon (95% confidence interval 0.7 to 3.8). The reduced risk of sudden death was consistent across different regions of the country, decades of the century, seasons of the year, days of the week, degree of competition (as measured by prize money), and course difficulty (as measured by winning race time). Each subgroup showed a protective association, though confidence intervals were wide in all cases (fig 3).

DISCUSSION

In this study of more than three million marathon runners over 30 years the risk of sudden cardiac death was small, occurring at a frequency of 0.8 for every 100 000 participants. This is equivalent to about two deaths per million hours of vigorous exercise. For each person who died from sudden cardiac death, we estimated a ratio of almost two lives saved from fatal

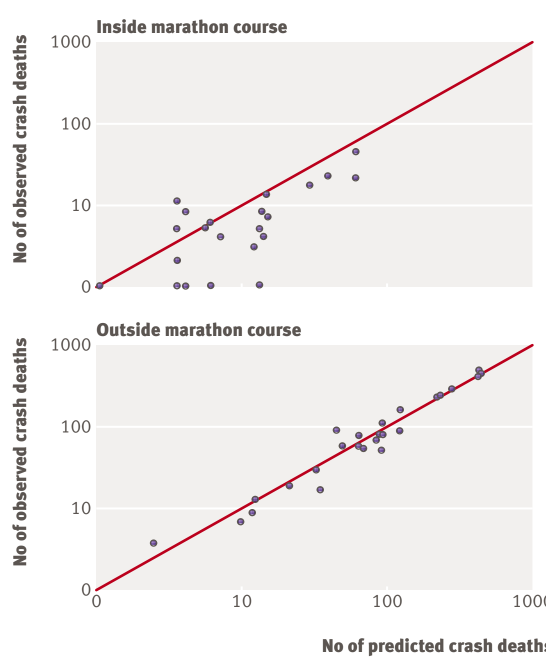

Fig 2 Comparison of observed crash fatalities on marathon days relative to predicted crash fatalities on control days. Top: counties inside marathon route; bottom: counties outside marathon route and data from corresponding hours of road closures. Each point represents one marathon site summed over all years. Note logarithmic scale and zero values plotted at 1

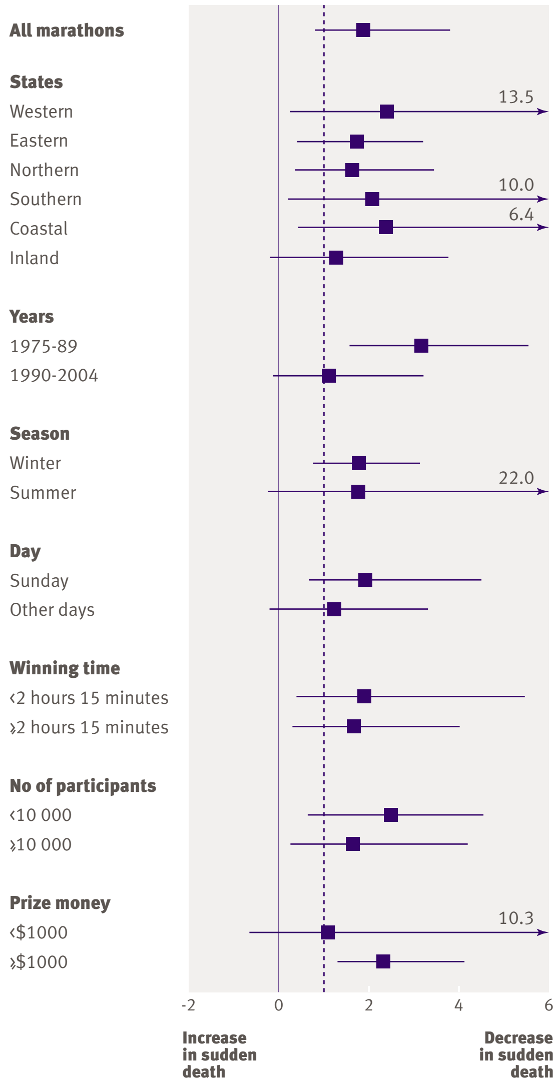

Fig 3 Ratio of crash fatalities prevented to cardiac deaths observed for average marathon. Values above zero indicate a decrease in crash deaths on marathon days relative to control days. Values over one indicate that number of crash deaths averted on marathon days exceeds number of cardiac deaths on marathon days. Full analysis appears at top based on all marathons and all times. 95% confidence interval calculated from bootstrap techniques. Weekday, winning time, number of participants, and prize money defined by most recent year

crashes that would have otherwise occurred (with comparable demographic profiles of cardiac deaths and crash deaths). The results were consistent in different parts of the country, decades of observation, and objective characteristics of the race. From a public health perspective these data suggest that running a marathon is no more dangerous than typical community activity on US roads.

Societal perspective

Because we used a retrospective ecological design to study risk our study does not prove that the individuals who die from running a marathon might have been saved from a motor vehicle crash. At the extreme, perhaps the reductions in crash deaths reflect the lives of spectators and uninvolved members of the community saved because of road closures. Previous research, however, shows that those who die in motor vehicle crashes are sometimes young healthy members of society and similar to participants in marathons.[25] Furthermore, analysis of demographic characteristics showed overlap between the two groups of sudden death identified in our study. Depending on personal lifestyle, therefore, the observed ratio implies that participants in marathons may lower societal risk but may or may not decrease their personal risk.

Individual psychology

Another limitation of our research is that we evaluated sudden death using numerical data whereas human psychology causes people to focus on some causes of death while neglecting others.[26] Cardiovascular deaths in athletes are shocking. Identified lives are more salient than statistical lives, thereby slanting community consciousness away from motor vehicle crashes. Bizarre deaths seem more newsworthy than common causes of death, and the different types of sudden death are not portrayed equivalently. Losses loom larger than the corresponding gains, so that a partial reduction of a common cause of death (vehicle crashes) seems no consolation for even a single death in a marathon runner. Moreover, fatalities at sporting events provide a convenient way for some people to rationalise their inactivity.

Beyond marathons

Our research has many other limitations. The data do not account for sudden cardiac deaths during training or after racing (although the physiological and psychological stress would presumably be smaller than during a marathon). We studied fatalities and not soft tissue injuries or other incidents that are not immediately life threatening.[27-30] Our study focuses on marathons and not other forms of exercise as the diversity and subtleties of each sport make related questions difficult to tackle from a scientific perspective. The analysis excluded small marathons, yet the pattern suggested that marathons with fewer participants showed a somewhat higher protective association. In addition, our study did not account for the potential enhanced health from regular exercise or how the quality of care at marathon sites might be improved.[31]

Clinical implications

Clinicians interested in preventing sudden cardiac death may be surprised by the low risk associated with marathon running. The rate we observed was significantly below that reported from research on small samples provoked by signal events (1/50 000)[32-36]; smaller than the risk of any type of crash associated with driving 42 km (1/15 000)[37]; and about the same as the baseline hourly risk of death for a middle aged man.[38] Our results also imply that the screening that prevailed

WHAT IS ALREADY KNOWN ON THIS TOPIC

Running a marathon can lead to sudden death, as documented 2500 years ago

Such fatalities at sporting events attract broad attention in modern media

WHAT THIS STUDY ADDS

The absolute risk is much lower than estimated by small studies provoked by signal events

The relative risk is smaller than the risk of a motor vehicle fatality on the same roads during the same time intervals

The final 1.6 km of the marathon represents less than 5% of the total distance yet accounts for almost 50% of the sudden cardiac deaths

for the past 30 years (medical assessment and self selection) yielded participants with a low baseline risk.[39 40] Hence, new technologies proposed for future screening would need to be inexpensive (<$100 (£49, €68) per patient) and extremely accurate (specificity >99%) to be cost effective.[41] A healthcare provider with limited resources, therefore, might be better served through enhanced efforts towards resuscitation rather than screening.

Policy relevance

Our study dispels a popular misconception and thereby also has policy implications. The results highlight the ongoing frequency of road crashes and how brief changes in driving can lead to a measurable reduction in health losses. A greater awareness of this issue might provide some context in the interpretation of widely publicised sports fatalities. The net decrease in sudden deaths we observed may bolster general support for aerobic exercise and temper a few lawsuits that follow from the occasional sudden cardiac death.[42 43] The distribution of cardiac deaths suggests that paramedic staffing for marathons should be planned on the basis of numbers of participants and that the last half of the marathon (and the last 1.6 km in particular) is the priority for resuscitation resources, ambulance preparedness, and pre-planned departure routes.[44] The results also indicate that, for participants, the final sprint with sudden cessation may be more dangerous than generally realised.

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