

Risk for Sudden Cardiac Death Associated With Marathon Running

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Objectives. This analysis was performed to quantitatively assess the relative risks, associated with underlying cardiovascular disease, incurred in the course of intense competitive sports.

Background. Sudden cardiac death during athletic activities is a highly visible event, and controversy persists regarding the true risks associated with participation in sports.

Methods. The prevalence of sudden death was assessed in two systematically tabulated groups of endurance runners competing in the annual Marine Corps (1976 to 1994) and Twin Cities (1982 to 1994) marathons, held over a cumulative 30-year period.

Results. A total of 215,413 runners completed the races, and four exercise-related sudden deaths occurred, each due to unsuspected structural cardiovascular disease. Three deaths occurred during the race (after 15 to 24 miles [24 to 38.4 km]) and the other immediately after its completion. The ages were 19 to 58 years (average 37), and three were men. Three of the sudden deaths were due to atherosclerotic coronary artery disease (narrowing of two or three vessels) and one to anomalous origin of the left main

coronary artery from the right sinus of Valsalva. None of the four runners had prior documentation of heart disease or experienced prodromal symptoms, and two had previously completed three marathon races each. The overall prevalence of sudden cardiac death during the marathon was only 0.002%, strikingly lower than for several other variables of risk for premature death calculated for the general U.S. population.

Conclusions. Although highly trained athletes such as marathon runners may harbor underlying and potentially lethal cardiovascular disease, the risk for sudden cardiac death associated with such intense physical effort was exceedingly small (1 in 50,000) and as little as 1/100th of the annual overall risk associated with living, either with or without heart disease. The low risk for sudden death identified in long-distance runners from the general population suggests that routine screening for cardiovascular disease in such athletic populations may not be justifiable.

(*J Am Coll Cardiol* 1996;28:428-31)

Sudden unexpected death during sporting activities is usually due to underlying and often unsuspected heart disease (1-18). Such catastrophes often attract substantial public attention (19), and considerable uncertainty persists regarding the precise risks associated with training and competition. The paucity of such risk assessment data has constituted a substrate for heightened anxiety in both the medical and lay communities (20,21), particularly regarding whether long-distance running and similar vigorous exercise may be hazardous to athletes with unsuspected cardiovascular disease (1,3,11-15). Indeed, distance running has become an immensely popular sporting activity in the United States, involving a growing proportion of the general public. For this reason, we chose to study runners participating in the marathon to assess and place into perspective the potential adverse cardiovascular risks associated with intense training and competition.

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Manuscript received September 28, 1995; revised manuscript received January 19, 1996, accepted March 12, 1996.

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Methods

Selection of subjects. The registries and case records of two long-standing annual marathon race programs usually held in October and November were reviewed, with the participants comprising the study population: 1) Marine Corps Marathon (Washington, D.C.), 1976 to 1994; and 2) Twin Cities Marathon (Minneapolis-St. Paul, Minnesota), 1982 to 1994. These marathon events were selected because of their accessibility to the general athletic community, considerable attention to detail in race organization and availability of reliable and systematically tabulated data over substantial periods of time. There were no special qualifying criteria for participation in either marathon. For those athletes who died, a retrospective analysis of the medical and athletic history was performed using available records and telephone interviews.

Results

Demographics of the marathon races (Table 1). From 1976 to 1994, 215,413 runners in the Marine Corps and Twin Cities marathons successfully completed the course distance (26 miles [41.6 km] and 285 yd [260 m]), with the majority (155,034 [72%]) participating in the larger and older Marine Corps event. The marathon runners were predominantly men (82%), and their average age was 37 years.

Analysis of sudden deaths (Table 2). A total of four sudden deaths occurred during or shortly after completion of

Table 1. Demographics of Two Marathon Populations

Marathon	No. of Years	Race Finishers						Sudden Cardiac Death		
		Total	Average/yr	% of Entrants*	Mean Age (yr)	% Men	% With Time <3 h	No.	% of Race Finishers	
Twin Cities	13	60,379	4,644	74.3	37.4	79.4	10.0	1	0.002	
Marine Corps	19	155,034	8,160	76.6	36.8	84.0	2.4	3	0.002	
	Total:	32	215,413	6,732	75.9	37.1	82.2	—	4	0.002

*Although the number of race entrants (those providing a completed prerace application and the fee) was known, it was not possible to accurately ascertain the precise number of entrants who actually started each race. Therefore, participation in the marathon was measured (and expressed) in terms of the most reliable data available (i.e., the number of runners who completed the race distance).

the marathon race. All deaths occurred during the most recent 10 years of the study period, with one each in 1986, 1989, 1990 and 1993 (Fig. 1); three deaths occurred during the Marine Corps Marathon and one during the Twin Cities Marathon. The ages were 19 to 58 years; three were men and one was a woman.

The prevalence of sudden cardiac death among the 215,413 marathon race finishers was 0.002%, or 1 in 50,000. When the average racing time for marathon finishers is estimated to be ~4 h, then the risk for sudden death may also be expressed as 1 in ~215,000 h of running.

Each of the four deaths proved to be due to underlying structural cardiovascular disease at autopsy. Three runners, all men, had coronary artery disease with atherosclerotic narrowing $\geq 50\%$ of the cross-sectional lumen area of either two major extramural arteries (case 2) or three arteries (cases 3 and 4). The fourth athlete, a 19-year old woman (case 1), had anomalous origin of the left main coronary artery from the right sinus of Valsalva (22). At autopsy, the left main coronary ostia appeared elliptical, and the artery followed a course between the aorta and pulmonary trunk until its bifurcation into the left anterior descending and left circumflex arteries. Each of the three main coronary arteries was free of atherosclerosis. None of the four athletes had evidence of substantial myocardial fibrosis, although small focal scars or necrosis was evident in two. Each of the three athletes who died of coronary artery disease also showed an increase in heart weight (300 to 525 g) and left ventricular wall thickness (13 to 22 mm). Detailed wall thickness data from all left ventricular segments and, hence, septal/free wall ratios were not available. An examination of the conduction system was not performed in these hearts. Results of postmortem toxicologic examinations of blood and urine were normal.

Three of the four runners collapsed without apparent warning during the race after 15, 23 and 24 miles (24, 36.8 and 38.4 km) (cases 1, 2 and 4, respectively). The fourth runner, a 40-year old man with coronary artery disease (case 3), collapsed 15 min after the race; he had experienced chest pain after running 20 miles [32 km] but completed the remainder of the race despite this symptom.

Of the four runners who died, two had successfully completed three previous marathon races, and the other two were competing in their first marathon. All four had trained intensively before the race, running 40 to 100 miles [64 to

160 km]/week; none reported experiencing prodromal cardiac symptoms during training or prior competition, nor had they previously documented structural heart disease. Two runners (cases 3 and 4) had a history of systemic hypertension for which medications were administered. In only one athlete was there a family history of sudden death (case 4).

Comparative risk assessment. The annual probability of premature death was estimated for a variety of circumstances using the U.S. Vital Statistics for persons 15 to 54 years of age, and was expressed as an average annual risk taken from 3 years of data (1979, 1990 and 1991) (23). These values were compared with the risk calculated for running one marathon. For example, risk associated with the marathon proved to be less than that associated with general living overall ($\times 120$), cardiovascular disease ($\times 23$) or accidents ($\times 19$).

Discussion

Occurrences of sudden death on the athletic field are of intense interest to both the medical and lay communities (19). Such catastrophes in trained athletes are usually due to underlying and unsuspected structural cardiovascular disease (1-18). However, there are relatively few quantitative data defining the risks for sudden cardiac death associated with training or competition within well defined athletic populations (3,17,20,24). Therefore, to further analyze this problem, we used marathon running as a model. The marathon race represents a vigorous and aerobic competitive sport requiring intensive training, characterized by a high level of public participation within a broad age spectrum. In addition, marathon runners can be exposed to extreme and unusual environmental conditions associated with alterations in blood volume and hydration that may theoretically enhance their risk for arrhythmias and cardiovascular events.

The present study analyzed two marathons that are traditionally open to all registrants to assess the potential for sudden death during competitive sports within the general athletic population. Based on our data in >200,000 runners, we calculated the risk for sudden death to be very small—0.002% or 1 in 50,000 race finishers. These findings suggest that participation in the marathon is associated with a low risk for adverse consequences, despite the fact that a small (but undefined) proportion of the participants undoubtedly had

Table 2. Clinical and Pathologic Findings in Four Sudden Cardiac Deaths Associated With Running the Marathon

Case No.	Age (yr)/Gender	Year	Marathon	Disease	Narrowed Coronary Artery (≥50%)			Heart Weight (g)	LV Wall Thickness (mm)	Myocardial Fibrosis/Necrosis	No. of Prior Marathons	Time of Collapse	Heart Disease	
					Prox LAD	LCx	RCA						Patient	Family
1	19/F	1990	Marine Corps	Anomalous LMCA	0	0	0	300	13	0	0	24 miles	0	0
2	32/M	1986	Marine Corps	CAD	90%	—	100%	440	"Concentric LVH"	Focal-PM	3	15 miles	0	0
3	40/M	1989	Twin Cities	CAD	100%*	75%	75%	470	15	Focal	0	15 min after completing race†	HPT	0
4	58/M	1993	Marine Corps	CAD	100%	50%	50%	525	22	0	3	23 miles	HPT	+

*Occlusive thrombus identified. †Chest pain at 20-mile mark. CAD = coronary artery disease; F = female; HPT = systemic hypertension; LAD = left anterior descending coronary artery; LCx = left circumflex coronary artery; LMCA = left main coronary artery; LV = left ventricular; LVH = left ventricular hypertrophy; M = male; PM = papillary muscle; Prox = proximal; RCA = right coronary artery; 0 = absent or none; + = present (premature sudden death in father at age 47 years).

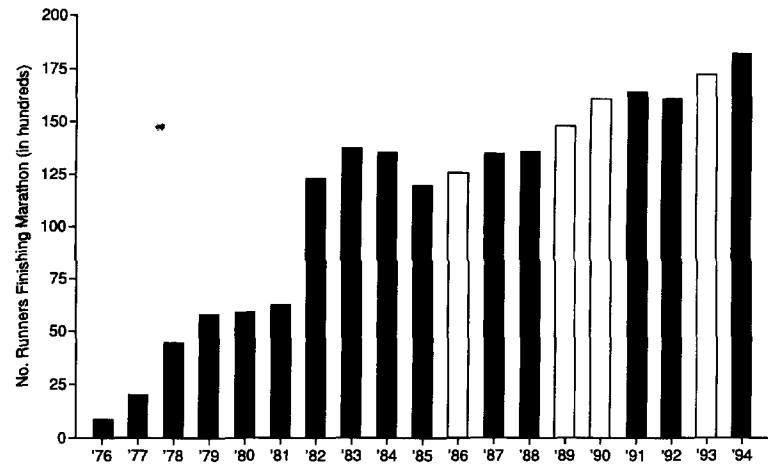
competed with unsuspected cardiovascular conditions (most likely coronary artery disease). Indeed, based on our calculations, the overall risk of living for 1 year (incorporating all causes of mortality including cardiovascular disease) (23) was >100 times greater than the risk of running in a single marathon race. Furthermore, the mortality for all forms of accidents was almost 20 times greater than that associated with the marathon (23). However, when expressed in terms of the risk for sudden death or cardiac arrest per man-hours of competition, marathon running (1 death/215,000 h) proved to be somewhat less safe than certain other sporting activities, including general and noncompetitive forms of exercise (1/375,000 h) (25), jogging (1/396,000 h) (3) or cross-country skiing (1/607,000 h) (26).

We should point out that because it was not possible to accurately determine the number of runners starting each race, we used marathon finishers as the denominator for calculations of risk. Because three of the four deaths occurred during a race, and therefore the runners were regarded as nonfinishers, the prevalence of sudden death reported here may be slightly overestimated.

Certain demographic and clinical features of the four exercise-related sudden deaths are worthy of discussion. Three deaths, all in male runners 32 to 58 years old, were due to acquired atherosclerotic coronary artery disease with either two- or three-vessel involvement, and little or no evidence of prior myocardial infarction. The other athlete (19 years old) had a congenital coronary malformation with anomalous origin of the left main coronary artery from the right sinus of Valsalva (22). These findings are consistent with previous observations in trained athletes who died of cardiovascular disease. A variety of congenital cardiac diseases account for athletic field catastrophes in younger athletes (2,4-10,17-19), whereas atherosclerotic coronary artery disease predominates in older athletes (1,3,11-16,24,27). In contrast, the low prevalence of sudden death that we identified with marathon running is consistent with the previous observation that sustained levels of vigorous physical exercise may reduce the risk for catastrophic events (20,28). Indeed, that two of the three runners who died of coronary artery disease had each previously completed three marathon races demonstrates that some athletes with cardiovascular disease are capable of tolerating intensive training and competition over long periods of time without experiencing symptoms or collapse (29,30).

Study limitations. Certain limitations are relevant to utilizing the marathon as a model for calculating the risk of sudden death associated with athletic competition. For example, marathon runners are subject to a certain degree of self-selection because of the intense training required in their sport. Hence, athletes previously experiencing exercise-related functional impairment or evidence of myocardial ischemia due to heart disease are less likely to have appeared in our population. For these reasons, we probably can not assume that the frequency with which sudden death occurs (or heart disease is present) in a large cohort of marathon runners is necessarily the same as in other strenuous sports.

Figure 1. Participation in the marathon race over a 19-year period in both Washington, D.C. and Minneapolis-St. Paul, Minnesota. The years of occurrence of sudden death are shown as **open bars**.



Conclusions. There has been substantial interest in the potential value and feasibility of preparticipation screening for cardiovascular disease in large populations of trained athletes (31,32). Although the present study does not offer definitive resolution of such screening issues, the particularly low prevalence of sudden death that we identified over a 30-year period suggests that the routine screening of such an athletic population may not be entirely justified in terms of the cost and resources required.

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