

*Contemporary Themes***Sudden cardiac death in sport**

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After running to Athens from Marathon in 490 BC, bringing the news of victory over the Persians, Pheidippides, who was a trained runner, is reported to have collapsed and died.¹ The number of case reports of similar events during strenuous physical activity has increased, particularly over the past 10 years, and has paralleled a boom in sporting activity. In 1982 the London marathon alone attracted 16 350 competitors. This increase in popularity has also been observed in other sports, most notably squash, track and field athletics, and swimming. Accompanying the boom in participation has been a disturbing increase in reports—often in the media—of sudden death associated with strenuous sports such as marathon running and squash. Hence it is important to consider the strength of the association between sudden death and sporting activity.

Although occasional deaths are attributed to other causes such as subarachnoid haemorrhage,² road traffic accident,³ and acute gastrointestinal bleeding,⁴ the most frequent cause of death is cardiac.⁵⁻⁷ We have therefore reviewed published reports in an attempt to determine how common such deaths are and the factors leading to death. We also provide some recommendations which we hope will reduce their frequency. For this purpose we have defined sudden death in sport as death occurring either during a medically unsupervised pursuit or in the first hour thereafter.

Frequency of sudden death associated with sport

Vuori *et al*, in a study of sudden death and physical activity, reviewed 2606 cases⁶ and concluded that, for the general population, sport could not be incriminated as a cause of sudden death. In a review of 40 000 American servicemen dying between 1942 and 1946,⁸ however, Moritz and Zamcheck concluded that strenuous activity was probably dangerous in people suffering from severe coronary disease. Nevertheless, the activity of only 127 of the subjects was known at the time of death and only 23% of the deaths occurred during strenuous exertion. Adelson found that 55% of sudden cardiac deaths occurred during light activity, 21% during sleep, and 5% during strenuous activity.⁹ Although frequently quoted, the relevance of these findings to sport is doubtful, as the study population consisted mainly of alcoholics and vagrants. Pell and D'Alonzo¹⁰ and Kuller *et al*¹¹ also found no relation between sudden death and strenuous physical activity. In contrast, other studies¹²⁻¹⁴ have noted significant numbers of deaths occurring during strenuous physical activity.

Published findings on the relation between sudden death and degree of activity are therefore inconsistent. Probably also in many deaths considered to have been precipitated by activity the nature of the activity was not sufficiently severe to constitute sport.

The determination of a true incidence of sudden death in sport is hindered by inadequate registration and investigation of each case. The level of activity at the time of death is not recorded in the official figures. Most of these events are the subject of forensic investigation, but the place of death is normally recorded as the hospital at which death was certified. It is also true that such inquiries are concerned with the pathological cause of death rather than the activities surrounding the death.

Despite these difficulties, attempts have been made to evaluate the statistical risk of sudden death during sporting activity. In rugby football Opie estimated that a death will occur every 50 000 "rugby-hours" in players and every 3000 "referee-hours."⁵ Even taking into account the greater age of referees, the latter figure seems unrealistically high. Koplan calculated that, by chance alone, 0.77/100 000 joggers could die each year, without there being any relation of the activity to sudden death.¹⁵ A study of the incidence of death during jogging in Rhode Island recently showed that the incidence was 17 times Koplan's estimate.⁴ Nevertheless, only one of 7620 joggers died each year, emphasising the rarity of such events in joggers.

In addition to these attempts to define the statistical risk are several reports of death during various sports (see table). Of 109 sudden

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Sudden death occurring during or within one hour of sporting activity. Collated data from references 2, 4, 5, 19, 21, 26-28, and 33

	Cause of death*					
	Coronary artery disease†	Hypertrophic obstructive cardiomyopathy	Coronary artery anomaly	Myocarditis	Conduction disorders	Ruptured aorta
No of subjects	80	15	8	3	2	1
Male	80	13	8	3	2	1
Female	0	2	0	0	0	0
Mean age (SD) in years	40 (9.1)	2	0	19 (6.2)	0	0

* In 34 of all deaths subjects were reported to have prodromal symptoms.

† Thirty four subjects had positive risk factors for coronary atherosclerosis.

deaths associated with sport appearing in the medical literature, 51 occurred during or immediately after running, 32 in rugby football and soccer or American grid iron football, nine in basketball, four in tennis, and the other 13 in various sports.

It is surprising that, despite a large number of deaths reported by the media in Britain and estimated at 27 a year¹⁶ associated with squash, we know of no detailed studies.

Thus there is a small risk of sudden cardiac death associated with vigorous sporting activity. Although others have attempted to evaluate this risk, their conclusions should be regarded as tentative. The actual risk can be determined only by a national attempt to collate the relevant data.

Causes

CORONARY HEART DISEASE

Although we realise that case reports may be incomplete and therefore may not be entirely representative, a few obvious features emerge from the table. The sample included a preponderance of male subjects, and coronary artery disease accounted for 80 (73%) of all 109 deaths, 34 (42.5%) of them occurring in men with documented risk factors for the disease. Those dying from coronary artery disease were significantly older ($p < 0.001$) than those dying from structural cardiovascular abnormalities (mean ages 40 (SD 9.1) and 19 (6.2) years respectively). In addition, of the group as a whole, 34 subjects (31%) suffered prodromal symptoms such as angina or extreme fatigue.

Immunity to atherosclerosis has been reported in Masai warriors, who herd cattle on foot,¹⁷ and Tarahumara Indians, who take part in ceremonial runs.¹⁸ Much controversy surrounded an assertion by Bassler in 1977 that fatal coronary artery disease had never been found in a marathon runner.¹⁹ He postulated that marathon running may protect against atherosclerosis but that running shorter distances may have no protective effect. Opie later described three cases of fatal myocardial infarction in marathon runners,²⁰ and subsequently further reports appeared.²¹ Bassler also claimed that coronary arteries of marathon runners were "enlarged" and "widely patent." This was based on a pathology report of a marathon runner by Currens and White.²² On review of this case, however, the authors clearly stated that atherosclerosis of the coronary arteries was present, the lumen of the coronary arteries being reduced to 30% diameter at several sites. Several long distance runners have died from myocardial infarction: perhaps the most notable was Vladimir Kuts, who was gold medallist in both the 5000 and 10 000 metre events in the 1956 Olympic games. He died in 1975 after a myocardial infarction at the age of 48.²³

Hence although moderate and regular physical exercise may reduce the risk of coronary atherosclerosis, regular participation in strenuous sport does not confer immunity, as suggested. Perhaps more precise information will result from a current prospective study by the American Medical Joggers' Association,²⁴ whose 4000 members are taking part in a study comparing them with a group of randomly selected physicians with respect to coronary artery disease, exercise behaviour, and risk factors for coronary heart disease.²⁵

A series of case reports have analysed the factors surrounding sudden death in sport. Opie described 21 sudden deaths in sportsmen occurring within one hour after onset of symptoms, in which 18 were attributed to coronary artery disease.⁵ These cases concerned predominantly rugby football players and referees. In a study of 18 deaths during or after jogging, Thompson *et al* concluded that 13 had been caused by coronary heart disease.²⁶ Waller and Roberts described five cases of sudden death during running in male runners over 40.²¹ At necropsy all were found to have severe coronary artery disease.

On Rhode Island there were 11 cases of sudden death in joggers during 1975-80 attributed to coronary artery disease, the subjects having an age range of 28-74 years (mean 46 years).⁴

Thus coronary artery disease is the most frequent cause of sudden death in sport, particularly in those over 40.

STRUCTURAL CARDIOVASCULAR ABNORMALITIES

Structural cardiovascular abnormalities are the commonest cause of sudden cardiac death in young people. Maron *et al* reported 29 cases of sudden death in young (13-30 years), highly conditioned competitive athletes.²⁷ In 22 of these death occurred during or in the first hour after sporting activity. In the group as a whole 28 were found later to have structural cardiovascular abnormalities such as hypertrophic cardiomyopathy, which was present in 14.

Other abnormalities have included congenital anomalies of the coronary arteries, which account for a small proportion of deaths.^{2 27 28} The most frequent abnormality is anomalous origin of the left main coronary artery from the right coronary cusp. The risk of sudden death in subjects with this abnormality is 27%.²⁹ Hypoplasia and atresia of the coronary arteries have also been described and are associated with sudden death.³⁰

Valvular heart disease has not been a feature in published reports as a cause of sudden death in sport. As suggested by Lynch,² this probably reflects the easier detection of such abnormalities at routine medical examination.

OTHER CONDITIONS

Myocarditis has been suggested as a cause of death in sportsmen.^{31 32} Few cases, however, have been explained by myocarditis alone, although isolated reports describe myopericarditis² and chronic myocarditis in young sportsmen.²⁸ Myocarditis is probably not an important factor in sudden death.

Dysfunction of the conduction pathways in the heart leading to fatal arrhythmias has been reported.^{27 33} In these cases the arteries supplying the sinus node have exhibited bizarre medial hyperplasia and intimal proliferation, thus leading to ischaemia of the sinus node.

In many cases no gross pathological cause can be found for sudden cardiac death, but such a conclusion should be reached only after thorough pathological examination of the cardiovascular system, with particular reference to histopathology of the conduction systems.

Prevention

PREPARTICIPATION MEDICAL SCREENING

Since sudden and unaccustomed physical activity is believed to be more likely to precipitate heart attacks in the unfit,³⁴ it may be more important to "screen" these people before they begin a new sporting activity. Preparticipation medical screening, which has been advocated, would detect overt, potentially lethal cardiovascular disease, but it may be that such disease would have appeared earlier. Routine medical examination would, however, be useful in detecting asymptomatic hypertension but would be relatively insensitive in identifying asymptomatic coronary artery disease or those at risk of fatal arrhythmia. Exercise electrocardiography might help to improve the detection of those at increased risk and we agree with Chung,³⁵ who advocated screening by exercise electrocardiography for subjects over 40 or in younger subjects with positive risk factors for coronary artery disease before engaging in an exercise programme.

AVOIDANCE OF EXCESSIVE EXERCISE

All sportsmen should be aware of the small risk of sudden cardiac death associated with vigorous sporting activity. Subjects should select a sport suitable for their age and general physical condition. Unfit people should not begin to participate in vigorous, highly competitive sports without a period of preparation. Johnson *et al* advocated that exercise should be regular, and that submaximal, rhythmical efforts are preferable until a greater work tolerance has been developed.³⁶ Also the heart rate should not exceed 170 beats/min, particularly if the subject is over 35. In order to adapt to high work rates sportsmen should make an effort to warm up adequately. In addition, possibly as important is a "warm down" at the end of an exercise period. This may reduce the likelihood of arrhythmias in the immediate post-exercise period.³⁷

Exercise programmes for subjects at increased risk should ideally be supervised initially.

PRODROMAL SYMPTOMS

Prodromal symptoms such as chest pain or extreme fatigue are common before sudden death.³⁸ Exercising adults, who may deny these symptoms,^{5,6} should be encouraged to seek medical attention should any untoward symptoms occur during or before vigorous exercise. In these circumstances play should be discontinued. We are concerned about the overenthusiasm of marathon runners and spectators who help runners to the finishing line when they are on the brink of collapse. This should be discouraged, and may be potentially dangerous.

It would also be wise, until further information is available, to avoid participation in vigorous sport when feverish or having symptoms of a respiratory tract infection.

AVOIDANCE OF THERMAL STRESS

Since high temperature increases heart rate and may induce arrhythmias³⁹ a hot bath or shower immediately after exercise should possibly be avoided. Vigorous activity in extreme heat should also be avoided—in this instance the additional factors of fluid and electrolyte loss may play a part in causing death. Such environmental factors are evident on many squash courts in Britain. In endurance sports such as marathon running fluid and electrolyte loss should be compensated as far as possible. Although "feeding stations" are available at most marathon meetings, not all athletes use this service adequately.

SMOKING

Smoking should be avoided by all sportsmen. Not only is smoking incriminated in coronary artery disease,²⁵ but it can cause an increase in serum free fatty acids⁴⁰ and release of catecholamines,⁴¹ which may interact with one another to cause arrhythmias,⁴² particularly in the immediate postexercise period.

Conclusions

There is a small risk of sudden cardiac death in subjects participating in vigorous sport. This risk is greater in those with asymptomatic cardiovascular disease, the more overt forms of which might be detected by medical screening. There is a group of patients, in general over 40, with asymptomatic coronary artery disease who would not be identified by screening. It may be that those at risk of coronary artery disease—for example, those over 40—should participate in less vigorous sport. Sportsmen should not ignore untoward symptoms, and if such symptoms develop, they should either stop or avoid participation before seeking medical advice. In addition, sportsmen and those concerned with sport should be aware of the risks. Following the precautions outlined above will, we hope, reduce the number of these tragic deaths.

References

¹ Herodotus. *The histories*. De Selincourt A, transl. New York: Penguin Books Inc, 1954:397-8.

- ² Lynch P. Soldiers, sport and sudden death. *Lancet* 1980;ii:1235-7.
³ National Safety Council. *Accident facts*. Chicago: NSC, 1981.
⁴ Thompson PD, Funk EJ, Carleton RA, Sturner WQ. Incidence of death during jogging in Rhode Island from 1975 through 1980. *JAMA* 1982; **247**:2535-8.
⁵ Opie LH. Sudden death and sport. *Lancet* 1975;ii:263-6.
⁶ Vuori I, Makarainen N, Jaaskelainen A. Sudden death and physical activity. *Cardiology* 1978;**63**:287-304.
⁷ Jokl E, McLellan JT. *Exercise and cardiac death*. Baltimore, Md: University Park Press, 1971.
⁸ Moritz AR, Zamcheck N. Sudden and unexpected deaths in young soldiers. *Archives of Pathology* 1946;**42**:459-593.
⁹ Adelson L. Sudden death from coronary disease—the cardiac conundrum. *Postgrad Med* 1961;**30**:139-47.
¹⁰ Pell S, D'Alonzo CA. Immediate mortality and five year survival of employed men with a first myocardial infarction. *N Engl J Med* 1964; **270**:915-22.
¹¹ Kuller L, Lillienfeld A, Fisher R. An epidemiological study of sudden and unexpected deaths in adults. *Medicine* 1967;**46**:341-61.
¹² Spain DMC, Bradess VA. The relationship of coronary thrombosis to coronary atherosclerosis in ischemic heart disease. *Am J Med Sci* 1960; **240**:701-10.
¹³ Armstrong A, Duncan B, Oliver MF, *et al*. Natural history of acute coronary heart attacks. A community study. *Br Heart J* 1972;**34**:67-80.
¹⁴ Wikland B. Medically unattended fatal cases of ischaemic heart disease in a defined population. *Acta Med Scand* 1971;suppl 524.
¹⁵ Koplán JP. Cardiovascular deaths while running. *JAMA* 1979;**242**:2578-9.
¹⁶ Fowler AW. Cause of death on squash courts. *On Call* 1980;**14**:7.
¹⁷ Biss K, Ho KJ, Mikkelsen B, Lewis L, Taylor CB. Some unique biological characteristics of the Masai of east Africa. *N Engl J Med* 1971;**284**:694-9.
¹⁸ Groom D. Cardiovascular observations in Tarahumara Indian runners—the modern Spartans. *Am Heart J* 1971;**81**:304-14.
¹⁹ Bassler TJ. Marathon running and immunity to athero-sclerosis. *Ann NY Acad Sci* 1977;**301**:579-92.
²⁰ Opie LH. Long distance running and sudden death. *N Engl J Med* 1975; **293**:941-2.
²¹ Waller BF, Roberts WC. Sudden death while running, in conditioned runners aged 40 years or over. *Am J Cardiol* 1980;**45**:1292-1300.
²² Currens J, White PD. Half a century of running. *N Engl J Med* 1961;**265**:251-5.
²³ Anonymous. Death of Vladimir Kuts. *New York Times* 1975 Aug 19.
²⁴ Jones RJ. Mortality of joggers. *JAMA* 1982;**247**:2569.
²⁵ Kannel WB, Doyle JT, McNamara PM, Quikenton P, Gordon T. Precursors of sudden coronary death. Factors related to the incidence of sudden death. *Circulation* 1975;**51**:606-13.
²⁶ Thompson PD, Stern MP, Williams P, Duncan K, Haskell W, Wood P. Death during jogging or running: a study of 18 cases. *JAMA* 1979;**242**:1265-7.
²⁷ Maron BJ, Roberts WC, McAllister HA, Rosing DR, Epstein SE. Sudden death in young athletes. *Circulation* 1980;**62**:218-29.
²⁸ Jokl E, McLellan JT. Exercise and cardiac death. *JAMA* 1970;**213**:1489-91.
²⁹ Cheitlin MD, De Castro CM, McAllister HA. Sudden death as a complication of anomalous left coronary origin from the anterior sinus of Valsalva; a not-so-minor congenital abnormality. *Circulation* 1974;**50**:780-4.
³⁰ Ogden JA. Congenital abnormalities of the coronary arteries. *Am J Cardiol* 1970;**25**:474-9.
³¹ Barlow JB. Exercise, rugby football and infection. *S Afr Med J* 1976;**50**:1351.
³² Kocnar K, Rous J. Preventive approach to sudden cardiac death at sports performance. *Br J Sports Med* 1973;**7**:166-7.
³³ James TN, Froggatt P, Marshall TK. Sudden death in young athletes. *Ann Intern Med* 1967;**67**:1013-21.
³⁴ Shepherd AJ. Sudden death—a significant hazard of exercise. *Br J Sports Med* 1974;**8**:101.
³⁵ Chung EK. Exercise ECG testing: is it indicated for asymptomatic individuals before engaging in any exercise program? *Arch Intern Med* 1980;**140**:895-6.
³⁶ Johnson PB, Updyke WF, Stolberg DC, Schaefer M. *Physical education: a problem-solving approach to health and fitness*. New York: Holt-Rinehart-Winston, 1966.
³⁷ Carruthers M, Nixon P, Murray A. Safe sport. *Lancet* 1975;ii:447.
³⁸ Alonzo AA, Simon AB, Feinlab M. Prodromata of myocardial infarction and sudden deaths. *Circulation* 1975;**52**:1056-62.
³⁹ Taggart P, Parkinson P, Carruthers M. Cardiac responses to thermal, physical and emotional stress. *Br Med J* 1972;iii:71-6.
⁴⁰ Kurien VA, Yates PA, Oliver MF. The role of free fatty acids in the production of ventricular arrhythmias after acute coronary artery occlusion. *Eur J Clin Invest* 1971;**1**:225.
⁴¹ Opie LH, Norris RM, Thomas M, Holland AJ, Owen P, Van Noorden S. Failure of high concentrations of circulating free fatty acids to provoke arrhythmias in experimental myocardial infarction. *Lancet* 1971;ii:818.
⁴² Johnson RH, Walton JL, Krebs HA, Williamson DM. Metabolic fuels during and after severe exercise in athletes and non-athletes. *Lancet* 1969;ii:452-5.

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