Education and debate

Sudden cardiac death in sport—spectre or preventable risk?

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Keeping death off the roads: health and safety at work and play

The Association of Chief Police Officers is campaigning for all major public events using the highways in the United Kingdom to have a preparatory risk analysis. This is already done for the London marathon, which uses public highway and Royal Parks. Legally "duty of care" by the organisers to participants requires an appreciation of risk and possible action.

Risk analysis should include an assessment of the risk of sudden cardiac death to entrants in mass participation events such as the London marathon and the London to Brighton annual British Heart Foundation cycle ride. Both events attract thousands of participants, some with known heart disease, but many, inevitably from the numbers, with undiagnosed heart disease.

But are the cardiac risks in these events sufficient to warrant planned action, or should the spectre of sudden cardiac death be regarded as a rare and unwelcome intruder whose occasional presence cannot be prevented? Rare events, by their unpredictability, cannot always be prevented. Lightning strike kills a few sportsmen every year but would not be considered a significant or completely avoidable risk in the United Kingdom, whereas after Hillsborough, the risks of spectator panic and stampede at sports grounds are now covered by extensive legislation.

Britain has had a "laid back" approach to sudden cardiac death in sport, and the lay reaction to the tragedy of "Do something" may be answered by the scientific doctor, controversially, by saying "Don't just do something! Stand there! Until you know of something effective to do". Effective prevention of sudden cardiac death in sport would entail the following.

(1) Knowledge of the true extent of the problem. There is no centralised collection of statistics in the United Kingdom for sudden cardiac death in sport.
(2) Recognition of the multiple causes, some associated with structural heart disease and some not, and their prevalence in the general population and in athletes.
(3) Appropriate screening of all athletes at risk at appropriate intervals; both modality and frequency are controversial.
(4) Stratification of those at high risk from those at remote risk.
(5) An effective method of preventing those at high risk from competing, without excluding everyone with trivial cardiac "abnormalities" from participating in a healthy activity.
(6) Funding and enthusiasm for this activity. This can only come when it is seen to be (cost) effective in preventing sudden death, not only during sport, but subsequently for those excluded from sport. Enthusiasm would wane if screening were seen to be excluding large numbers of apparently healthy people from sporting activity or if those excluded from sport with severe heart disease died anyway.
(7) Expert and prompt resuscitation facilities to deal with cardiac arrest occurring at sporting events in those athletes not "screened out".

So few of these criteria can currently be realised, that the whole question of the appropriateness of embarking upon mass screening is questioned.[1]

The death of Anna Loyley

The dramatic death of Anna Loyley aged 26 in the Bath half marathon in March 1998 and the subsequent campaign of her parents has been covered in many national newspapers, as well as by American internet journalism and short pieces and letters in the *British Medical Journal*.[2 11] It led indirectly to a small conference on sudden cardiac death in sport. Organised by the National Sports Medicine Institute in March 1999 with support from the British Heart Foundation, many of these issues were addressed. An initiative from the National Sports Medicine Institute may follow.

FIRST AID AND ATTEMPTED RESUSCITATION

Anna, an experienced and well prepared asymptomatic runner, died after collapsing at the finish with what was eventually diagnosed as ventricular fibrillation. From evidence (collected by her family from eyewitnesses and from analysis of the automatic defibrillator recordings, which they arranged and paid for) presented at the inquest, it appears that there were delays in appropriate use of an automatic defibrillator for various reasons.[3]

(1) A pulse was apparently felt early in the resuscitation by one first aider which influenced subsequent management. Feeling a pulse is now regarded in the latest

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resuscitation guidelines as extremely unreliable, when there is other evidence of cardiac arrest, which there was. She fell lifeless and stopped breathing.

(2) The auditory prompts from the automatic defibrillator were drowned by the public address system at the finish, and while priority was being given to tracheal intubation at the expense of defibrillation, the visual cues on the display of the automatic defibrillator were apparently not noticed.

(3) Management of the resuscitation was complicated by the arrival of "Good Samaritan" doctors (one of whom had just run the race) who took over the difficult intubation. If they had not arrived, earlier priority might have been given to defibrillation.

According to the automatic defibrillator record, defibrillation was not attempted until after several minutes of ventricular fibrillation. After defibrillation, she was placed promptly in an ambulance. The regular complexes on the electrocardiogram (ECG) were followed by electromechanical dissociation and asystole. She was declared dead shortly after arrival at hospital.

At post mortem, verified by two cardiac pathologists, no structural disease of the heart was found and the death was attributed to "idiopathic ventricular fibrillation" or "sudden adult death syndrome".

Lack of any evidence of heart disease is found in some 2% of cases of sudden cardiac death in young sports people. Sudden cardiac death is uncommon in sports women, making Anna's death a particular rarity.

CORONER'S SUGGESTION OF COMPULSORY SCREENING

The first aiders and "Good Samaritan" doctors found cross examination by counsel for the Loyley family a traumatic experience. Anna had no previous relevant medical history and no family history of syncope, but the coroner, while exonerating the resuscitation team, suggested the universal screening of runners for these events, with at least a mandatory ECG.[3]

This recommendation appeared to be on the basis of the evidence of an expert witness who raised the possibility of long QT syndrome. This syndrome is a rare familial cause of repeated syncope and sudden death (about 10% of cases of sudden adult cardiac death), and is diagnosed in life by the history, family history, and ECG appearance, which unfortunately is inconstant, often normal, and, even if abnormal, may be subtle, requiring expert ECG analysis. Premorbid ECGs and ECGs of survivors of syncopal episodes from idiopathic ventricular fibrillation (sudden adult cardiac death syndrome) do not necessarily exhibit a long QT or other ECG abnormalities, and so the chances of preventing Anna's death by routine ECG are conjectural.

The campaign by her family and local MP Don Foster to make mandatory skilled advanced life support at all running events involving more than 300 participants has focused attention on the magnitude of the risks. Her case can be used to illustrate the problems.

Sudden cardiac death in sport

Sudden cardiac death in sport can be divided into three categories: commotio cordis in which a blow to the adolescent chest wall by a missile causes a fatal cardiac arrhythmia; sudden cardiac death in young athletes (below the age of 30), which is predominantly due to structural, usually inherited, heart disease, and attracts the most medical and media attention; sudden cardiac death from coronary artery disease, which is mainly a problem in athletes over the age of 30 and is the predominant risk in road running events such as marathons and half marathons.

Incidence

Figures on the incidence of sudden cardiac death in young athletes are not available in the United Kingdom, but it has been calculated in the United States to be 1 in 100 000 high school athletes, of whom 1 in 500 will have an identifiable, usually trivial, cardiac "abnormality".[4 5]

Risk of road races

The incidence of sudden cardiac death in road races in Britain overall is not known, but figures from the larger races suggest an incidence of 1 in 50 000 to 100 000 in marathons and half marathons. Similar figures have been calculated for marathons in the United States.[6 7]

In the London marathon, over 19 years there have been five deaths and five cardiac resuscitations in over 440 000 runs, with a median runner age of 39. Nine of the ten events were related to severe coronary disease. In the New York marathon, there have been three deaths in over 400 000 runs; it probably has a less coronary prone field of runners than the London marathon which attracts large numbers of charity entries.

These figures make an interesting comparison with the latest road and travel fatality figures from the European Union.[8] Running the London marathon in four hours has an equivalent risk to riding a motorcycle for two hours, 10 hours cycling, or being in a car or on a scheduled air flight for 28 hours (table 1).

Statistical clusters

There have been three deaths in the Bath half marathon out of 45 000 competitors, all like Anna's at the finish. This equates to a 14 times greater death rate for time spent running than

Table 1 Deaths in the London marathon (five in 19 years) compared with European Union travel statistics

Mode of travel	*Deaths/ 10^8 km*	*Deaths/ 10^8 h*	*Deaths/ 100 years*	*Relative risk*
London marathon 1981–99	25	250	2.2	7
Motorcycle	16	500	4.4	14
Bicycle	6.3	90	0.9	3
Car	0.8	30	0.3	1
Airline passenger	0.08	36.5	0.35	1
Rail	0.04	2	0.02	0.06

in the London marathon. This type of statistical cluster is easily interpreted as showing a high risk for participation if small numbers of selected events are sampled. A similar cluster has been dramatised recently in the sport of horse trials or eventing. There have been five rider deaths in four months from horses falling and rolling on their riders in 1999 in the United Kingdom. This cluster is compared with a total of 15 deaths in the last 17 years. Statistical analysis of risk requires large numbers of events to be sampled for appropriate conclusions to be drawn, although clusters may suggest an unrecognised or new cause.

Screening of young athletes

Routine screening of young athletes is mandatory in many European countries and has been introduced in Britain for select groups such as football apprentices. In Italy, a reduced death rate from hypertrophic cardiomyopathy has been credited to such screening.[9] Unfortunately screening of young athletes may disclose a preponderance of non-life threatening, usually inconsequential, cardiac abnormalities, such as mitral valve prolapse and mild degrees of cardiac hypertrophy on the borderline between the changes of athletes heart and hypertrophic cardiomyopathy. Much unnecessary anxiety may be produced. Life threatening conditions such as long QT syndrome and other forms of sudden adult death syndrome may reveal no abnormality on screening, and others such as the Swedish orienteering deaths from presumed *Chlamydia myocarditis*[10] would probably not have been prevented by an annual assessment. However, some lives could be saved, and there is a strong case for facilities to be available for screening young athletes at high risk—that is, those with a family history of sudden death and those with possible cardiac symptoms. Exertional syncope, exertional chest pain, cardiac arrhythmias, and paroxysmal breathlessness without wheeze merit urgent investigation in young athletes.

Screening of older athletes

The coronary prone middle aged runner is more at risk and should be made aware of the symptoms of heart disease and the paradox that, although, overall, exercise reduces the risk of coronary events, it may precipitate them in a small minority. Runners are not immune from coronary disease, and runners in the London marathon receive written medical advice encouraging them to seek medical attention, including exercise testing where appropriate, because of symptoms or high coronary risk. It admonishes them not to run if there are any medical doubts.

Medical certification and exclusion

Exclusion of "cardiac high risk" athletes after screening is easier within an established bureaucratic or tightly governed system, such as the FA football apprenticeship scheme, US high school or university sport, or the Italian licensing system, than in a traditionally laissez faire organisation such as amateur football or road running in Britain.

Mandatory medical certificates for participation in sport could encourage abuse, including forgery. Most large events, such as the big road races would have no facilities to verify up to 35 000 medical certificates from all over Britain and the world. How often would a runner have to be checked and how? The emphasis must be on educating athletes to take responsibility for their own fitness to compete and avoid undue risks.

Legally and ethically, athletic authorities would be wise not to claim that they can prevent sudden cardiac death in sport, but should help facilitate rapid access to cardiological testing facilities when there is good clinical indication or a high level of anxiety. The results need interpretation and sympathetic advice from cardiologists experienced in this field, who will be needed to counsel the athlete, coaches, and parents if anything untoward is found. They could advise on possible treatment, a less physically demanding recreation, or a career change to one not based on physical prowess in professional sport.

Resuscitation and event certification: ideal and practical

The Loyley-Don Foster proposals suggest professionalisation of the resuscitation teams at all road races involving more than 300 runners and the employment of an anaesthetist to deploy the team and be race medical director.

Most first aiders have been trained in cardiopulmonary resuscitation. Increasing numbers of ambulances are equipped with trained paramedics and automatic defibrillators. However, out of hospital cardiac resuscitation so far has a dismal survival rate of about 10%. The 50% survival rate in the London marathon is remarkably high, particularly as most arrests were not in close proximity to a defibrillator. One runner was even resuscitated from asystole.

Although the finish of a road race is probably the most dangerous time for cardiac arrest (all three deaths occurred at this stage in the Bath half marathon), only one of the ten cardiac arrests in the London marathon occurred in the finish area and, in many other races, deaths were reported to occur along the course.

Survival rates are directly related to speed of defibrillation from ventricular fibrillation, which is the most common cardiac arrest rhythm. The optimum chance of resuscitation (still only about 50%) is when defibrillation is available within one or two minutes of the onset of ventricular fibrillation. In a major participant event such as a marathon, this is an unobtainable ideal. Witnessing collapse, summoning a resuscitation team, making the diagnosis, obtaining a defibrillator, attachment of the defibrillator, checking the rhythm, charging the defibrillator, and giving a shock all take time. Such an ideal would require advanced life support teams with automatic defibrillators every 200–300 m along the course of a marathon or similar road race or a very large number of mobile rapid response patrols with guaranteed access to the whole course, a logistic nightmare for some races. In practice, aid

stations are only every one to three miles or even less frequent, and cardiac resuscitation defibrillators may only be available at the finish except in the biggest races.

The Loyley family campaign for mandatory advanced life support has suggested the employment of trained anaesthetists by race organisers as race medical directors, ready availability of automatic defibrillators along the course, and use of local authority ambulances and licensing of races on this basis. These proposals have caused consternation among the traditional athletics clubs who regard first aid and medical support as necessary for the common running ailments of blisters and musculoskeletal problems and do not regard cardiac arrest as a common or dominant problem. Who is right? What level of risk is acceptable in sport where part of the appeal is the hardship and bravado?

Most British races depend on medical support from the St John's Ambulance Brigade (St Andrew's in Scotland) or the Red Cross, which are staffed by unpaid volunteers. These are declining in numbers. Paid professional anaesthetists may be difficult to recruit for road races, and be inappropriate as race medical directors who have to face many problems other than cardiac arrest.

Generous direct payment of medical staff may have a damaging effect on recruitment of other volunteers who are essential for the safe running of these events. However, volunteers must give a professional level of service, and, if adequate volunteer medical support cannot be recruited, organisers may have to supplement them with professional paramedics and doctors.

Licensing of events also raises problems. Would events be inspected on the day? Would an event planned for months and with thousands of willing runners be cancelled because the anaesthetist, whose skills are rarely needed in a race, is called to the local hospital because of a staffing crisis and fails to turn up for the race?

Resuscitation services, including advanced life support, would seem appropriate for major prestige events which attract thousands of runners and considerable sponsorship, particularly when the field contains many inexperienced charity runners. Organisers of these events could advise runners of their gold standard medical support. Organisers of the traditional interclub run, which attracts a few hundred club runners and for which it would be difficult to organise and finance advanced life support, should also publicise the level of medical services if any that they provide. Gold, silver, and bronze levels of medical support could be agreed and advertised. All sports involve some hazards. Not all can realistically be prevented.

Duty of care may involve educating organisers and participants of the risks, but does not mean deploying medical resources disproportionate to that risk.

1 Macauley D. Does preseason screening for cardiac disease really work? The British perspective. *Med Sci Sport Exerc* 1998;Oct suppl:S345–50.
2 Loyley P, Loyley P. Medical rules are needed in marathons in the United Kingdom [letter]. *BMJ* 1999;**318**:1285.
3 Whitehouse RBH (HM Deputy Coroner). Notes of evidence at the inquest on Anna Louise Loyley at the Magistrates Court Bath on 15/16 October 1998.
4 van Camp SP, Bloor CM, Mueller PO, *et al*. Non traumatic deaths in high school and college athletes. *Med Sci Sports Exerc* 1995;**27**:641–7.
5 Maron BJ, Shirani J, Poliac LC, *et al*. Sudden cardiac death in young competitive athletes; clinical demographic and pathological profiles. *JAMA* 1996;**276**:199–204.
6 Williams RS, Schocken DD, Morey M, *et al*. Medical aspects of competitive distance running. *Postgrad Med J* 1981;**70**:41–50.
7 Maron BJ, Poliac LC, Roberts WO. Risk for sudden cardiac death associated with marathon running. *J Am Coll Cardiol* 1996;**28**:428–31.
8 ETSC update. *Crash risks in EU transport, June 1999*. ETSC, Rue du Cornet 34, Brussels.
9 Corrado D, Basso C, Schiavon M, *et al*. Screening for hypertrophic cardiomyopathy in young athletes. *N Engl J Med* 1998;**339**:364–9.
10 Willems S. Sudden cardiac death in young athletes: orienteering on Chlamydia pneumoniae? [editorial; comment]. *Eur Heart J* 1996;**17**:810–12.
11 Luke LC. Having advanced resuscitation facilities at end of marathons does not guarantee survival [letter]. *BMJ* 1999; **319**:581.