Pre-participation cardiac screening: Considerations for young athletes

Lee Ingle is Reader in Exercise Science for Health, Carnegie Research Institute, 209 Fairfax Hall, Leeds Metropolitan University, Beckett Park, Headingley, Leeds LS6 3QS. **Email:** L.Ingle@leedsmet.ac.uk

The sudden death of a young, apparently healthy athlete is a shocking, highly publicized event that results in a unified outpouring of emotion from both the media and general public alike. The incidence of sudden cardiac death (SCD) was thought to be reassuringly low with figures between 1: 160 000 cases and 1: 300 000 cases per year in athletes between the ages of 14 and 35 years in the United States (Van Camp et al, 1995; Maron et al, 2009). However, other recent data has shown a ten-fold increase in incidence. For example, in the Veneto region of Italy, a regional registry recording deaths of young athletes from SCD (ages 12–35 years) reported incidence rates of 1:28 000 prior to the implementation of a screening programme (Corrado et al, 2006). Similar incidence figures (1:27 000) in children and young adults aged 14–24 years were also reported in 11 US and Canadian cities (Atkins et al, 2009).

Therefore, the real incidence of SCD in young athletes is difficult to determine as many published studies use very different methodologies, and sample populations are often from different geographical locations making inter-study comparisons difficult (Drezner et al, 2009). Consequently, early studies may have greatly underestimated the true risk of SCD in young athletic populations. It would appear that males have a ten-fold greater incidence of SCD than females (Burke et al, 1999; Corrado et al, 2005; Corrado et al, 2006), perhaps as they are more likely to be engaged in competitive sports and greater training volumes than females. The demographic profile of a typical young person likely to be affected by SCD would be a young active male aged 15–22 years (Corrado et al, 2006).

To prevent SCD, a cardiac condition must initially be identified followed by an appropriate treatment pathway based on individual circumstances, which could involve surgery, device implantation, lifestyle alterations, pharmacological intervention, or a combination of these therapies (Anderson and Vetter, 2009). The first stage of the process is to identify the cardiac condition and for young athletes this may be through a pre-participation cardiac screening programme.

Pre-participation cardiac screening is an investigative tool designed to provide medical clearance for participation in sports through a systematic interrogation of individual cardiovascular health (Wilson et al. 2008). Specific modes of pre-participation screening have been debated within the scientific community for many years. Such debates are informed by issues of cost-effectiveness, rates of false positives and negatives, and ethical and legal concerns.

Several professional governing bodies including the European Society of Cardiology (ESC), International Olympic Committee (IOC), and the Fédération Internationale de Football Association (FIFA) have produced consensus statements recommending standard cardiac screening programmes that include, at the initial stage, a combination of resting electrocardiography (ECG), personal symptoms, and physical examination.

The American Heart Association (AHA) pre-participation screening programme focuses specifically on personal symptoms and physical examination (Maron et al, 2007). It anticipates that an extra annual programme cost of $2 billion would be required to include a resting ECG

Abstract

This article is the first of two focusing on the utility and evidence base for pre-participation cardiac screening in competitive athletic populations. The second article will focus on the diagnostic value of different screening modalities used in the large-scale screening of athletic populations. The current article, however, focuses on the incidence of sudden cardiac death (SCD) in young athletic populations and goes on to consider the effectiveness of cardiac screening programmes for reducing the risk of SCD.

Cardiac screening in athletic populations is problematic as it may be difficult to distinguish between physiological adaptations resulting from a specific exercise training stimulus and pathological conditions. Different types of chronic exercise training can induce eccentric or concentric myocardial hypertrophy, which may mimic pathological conditions. The final section discusses some of the practical issues that a clinician may face when needing to advise a young athlete to either stop or modify his/her habitual patterns of physical activity including future exercise considerations.

Key words

◆ Sudden cardiac death ◆ Screening ◆ Arrhythmias ◆ Cardiomyopathy

Submitted for peer review 4 June 2010. Accepted for publication 8 July 2010. Conflict of interest: None declared

examination. However, the US system is under close scrutiny as 80% of athletes who die as a result of SCD are asymptomatic and physical examination identifies few relevant disorders (Papadakis et al, 2008).

Effectiveness of cardiac screening programmes

In Italy, mandatory screening of all athletes through the Medical Protection of Athletic Activities Act has been in existence since 1979, and in excess of 6 million athletes have been screened (Corrado et al, 2005). The Italian model has seen a reduction in incidence of SCD from 3.6 cases per 100 000 per year before screening to 0.4 cases per 100 000 per year reported in 2003–2004 (Corrado et al, 2006). These data represent a 90% reduction in mortality since pre-participation screening was introduced and offer compelling evidence for the inclusion of a cardiac screening programme.

The physiological versus pathological heart

Long-term exercise training results in adaptations to cardiac structure and function. These alterations may appear to be confusing to the uninitiated as they may mimic specific pathological abnormalities that could result in heart disease (Huston et al, 1985). The type of exercise training conducted is the key stimulus for the type of cardiac adaptation achieved. For example, endurance or aerobic training such as distance running, cycling or swimming will, over time, result in increased maximal oxygen uptake and cardiac output, leading to increased volume load on the left ventricle. Conversely, long-term strength training activities such as weight lifting and wrestling may result in little change in maximal oxygen uptake and cardiac output but will result in pressure overload on the left ventricle (Maron, 2009).

In approximately 50% of athletes, long-term exercise training results in some degree of cardiac remodelling which may be evident on the ECG trace in ways that resemble pathological chamber enlargement and/or may mimic patterns seen in, for example, hypertrophic cardiomyopathy (Mitchell et al, 2005).

Pathological and physiological myocardial hypertrophy can be sub-classified into concentric or eccentric hypertrophy based on morphological changes that are dependent on the initial stimulus (Pluim et al, 2000). A pathological stimulus causing pressure overload (e.g. hypertension or aortic stenosis) produces an increase in systolic wall stress resulting in concentric hypertrophy) (McMullen and Jennings, 2007) (*Figure 1*). Conversely, a pathological stimulus causing volume overload (e.g. aortic regurgitation) results in an increase in diastolic wall stress and consequently leads to eccentric hypertrophy (Pluim et al, 2000).

In healthy athletic populations, long-term endurance/aerobic training may lead to increases in cardiac chamber size and left-ventricular mass (eccentric hypertrophy). Resting heart rate may be reduced (bradycardia) leading to excessive vagal tone at rest. This can produce abnormalities such as atrioventricular block and wandering atrial pacemaker on the resting ECG (Crawford, 2007).

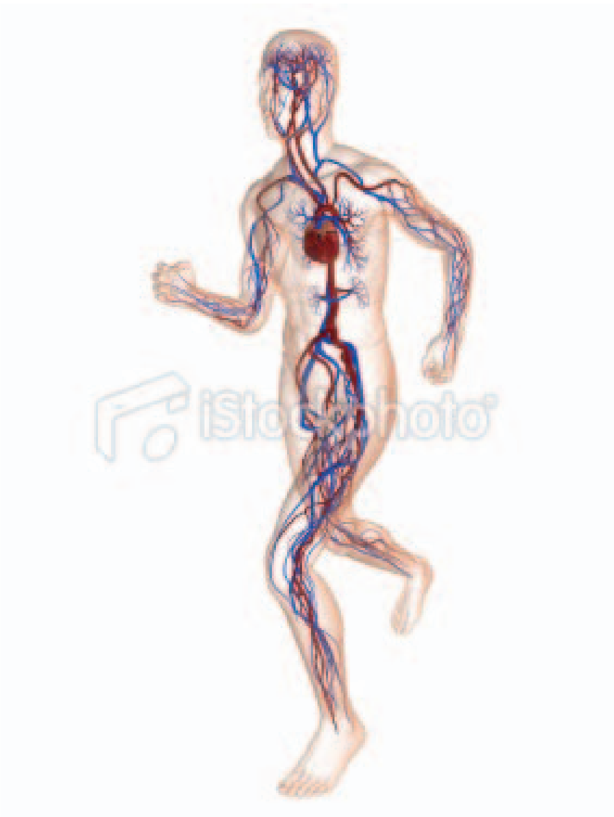
Furthermore, low resting heart rate (<60 bpm) may increase the frequency of premature ventricular contractions and short runs of ventricular tachycardia may be evident. However, in the trained athlete these rhythm disturbances often disappear following the start of exercise (Biffi et al, 2002).

Sophisticated cardiac imaging techniques such as echocardiographic deformation imaging have recently revealed that a moderate reduction in regional septal deformation should not be considered as pathological in endurance athletes with left ventricular hypertrophy (Teske et al, 2009). Long-term strength training, such as in weight-lifters, may increase left-ventricular wall thickness (up to 16 mm) and left-ventricular mass (concentric hypertrophy) (Pelliccia et al, 1991; Crawford, 2007). Highly trained athletes with cardiac chamber enlargement may also have systolic flow murmurs, and third and fourth heart sounds (Crawford, 2007).

For more detailed information on sport-specific changes in left-ventricular cavity size and wall thickness the interested reader is directed to Maron (2009).

Risks of exercise in athletes with cardiac conditions

The holistic benefits of exercise and physical activity are firmly established in the public health domain. However, while the incidence of cardiac-related deaths is very low,



Endurance or aerobic training will lead to changes in the heart over time, as may strength training there may be associated risks of exercise in individuals with underlying cardiac conditions. Vigorous exercise is more likely to trigger ventricular arrhythmias and SCD in vulnerable individuals (Maron, 2003).

Following screening, if a cardiac abnormality is identified, the young athlete's clinician should provide a recommendation for sports participation and provide general advice relating to habitual physical activity. Guidelines such as those published by the ESC should be used to assist clinical judgments (Pelliccia et al, 2005). For example, sudden bursts of acceleration involving high intensity activity should be avoided as should extreme environments (hot, cold, altitude, hyperbaric), and more 'dangerous' sports such as parachuting and bungee jumping. Performance enhancing and/or recreational drugs including stimulants should also be avoided. Low to moderate forms of exercise intensity such as recreational jogging or cycling, which involve a suitable warm-up and cool-down, may be more appropriate.

The clinician must weigh the theoretical increased risk of SCD associated with the engagement in exercise against the psychosocial and health benefits of sports participation (Anderson and Vetter, 2009). However, there is no guarantee that the young athlete will follow the medical guidance. Often a compromise between clinician and young athlete will be sought allowing, for example, the athlete to continue some level of engagement in a less demanding position (such as moving from an outfield player to a goalkeeper in football) (Anderson and Vetter, 2009). Such compromises need to be carefully evaluated by the clinician and will require consent from the coach of the specific sports team.

Clearly, there are a number of ethico-legal considerations balancing clinical necessity and psycho-social and health benefits from the perspective of the young athlete, which should be carefully considered before any final decision is reached.

Screening in the UK

In the UK, the charity Cardiac Risk in the Young (CRY) has been involved in cardiac screening for around 15 years, initially on an ad hoc basis. In recent years, since large-scale investment from the technology company Phillips, CRY has developed a nationally co-ordinated screening programme known as 'Save an Athlete'. However, the future role for cardiac screening in the UK is still under debate. Professional sporting associations need to evaluate the need for the development of clear and comprehensive screening programmes while carefully balancing the financial implications that such initiatives would no doubt involve.

Conclusions

Concern over the possibility that strenuous exercise may trigger previously undetected cardiac conditions in young athletes, causing sudden death, has led to the introduction of pre-participation screening programmes. In looking for abnormalities, health professionals need to take into account changes to the heart's structure and function that are the result of long-term excercise training.

While screening programmes are mandatory in some countries, in the UK their role is still under consideration. A further article will consider various models used for screening athletes for risk of SCD.

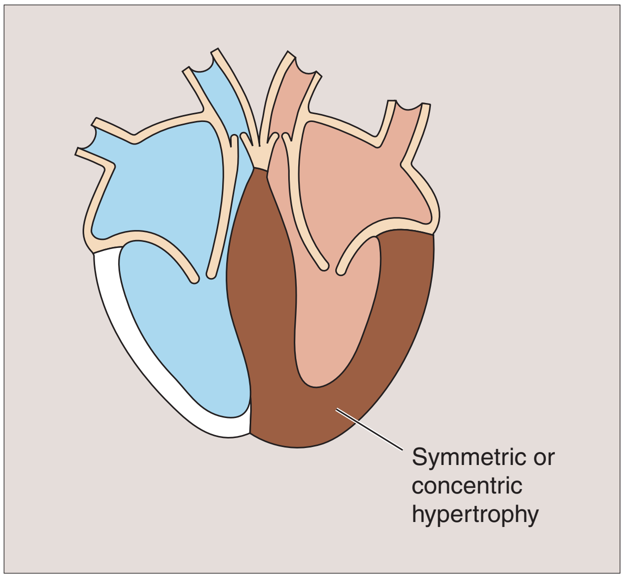


Figure 1. Concentric hypertrophy may be seen in conditions where there is pressure overload, but may also be seen in those undertaking long-term strength training.

Anderson BR, Vetter VL (2009) Return to play? Practical considerations for young athletes with cardiovascular disease. *Br J Sports Med* **43**: 690–5

Atkins DL, Everson-Stewart S, Sears GK et al (2009) Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. *Circulation* **119**: 1484–91

Biffi A, Pelliccia A, Verdile L et al (2002) Long-term clinical significance of frequent and complex ventricular tachyarrhythmias in trained athletes. *J Am Coll Cardiol* **40**: 446–52

Burke AP, Robinson S, Radentz S, Smialek J, Virmani R (1999) Sudden death in right ventricular dysplasia with minimal gross abnormalities. *J Forensic Sci* **44**: 438–43

Corrado D, Pelliccia A, Bjørnstad HH et al (2005) Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol - Consensus statement of the Study Group of Sport Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology. *Eur Heart J* **26**: 516–24

Corrado D, Basso C, Pavei A, Michieli P, Schiavon M, Thiene G (2006) Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program. *JAMA* **296**: 1593–601

Crawford MH (2007) Screening athletes for heart disease. *Heart* **93**(7): 875–9

Drezner J, Pluim B, Engebretsen L (2009) Prevention of sudden cardiac death in athletes: new data and modern perspectives confront challenges in the 21st century. *Br J Sports Med* **43**: 625–6

Huston TP, Puffer JC, Rodney WM (1985) The athletic heart syndrome. *N Engl J Med* **313**: 24–32

Maron BJ (2003). Sudden death in young athletes. *N Engl J Med* **349**(11): 1064–75

Maron BJ (2009) Distinguishing hypertrophic cardiomyopathy from athlete's heart physiological remodelling: clinical significance, diagnostic strategies and implications for preparticipation screening. *Br J Sports Med* **43**: 649–56

Maron BJ, Thompson PD, Ackerman MJ et al (2007) Recommendations

Key Points

- The incidence of sudden cardiac death in young athletes is unclear as ten-fold differences have been reported in the literature
- Pre-participation cardiac screening is an investigative tool designed to provide medical clearance for participation in sports through a systematic interrogation of individual cardiovascular health
- In Italy, a 90% reduction in incidence of SCD has been reported following the introduction of a cardiac screening programme providing compelling evidence for its inclusion in a health screening package
- Cardiac screening in athletic populations is problematic as it may be difficult to distinguish between physiological and pathological adaptations
- In a young athlete with a cardiac abnormality, the clinician must carefully balance clinical necessity with the potential psycho-social and health benefits of continued exercise.

and considerations related to pre-participation screening for cardiovascular abnormalities in competitive athletes: 2007 update: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism: endorsed by the American College of Cardiology Foundation. *Circulation* **115**: 1643–55

Maron BJ, Doerer JJ, Haas TS, Tierney DM, Mueller FO (2009) Sudden deaths in young competitive athletes: analysis of 1866 deaths in the United States, 1980-2006. *Circulation* **119**: 1085–92

McMullen JR, Jennings GL (2007) Differences between pathological and physiological cardiac hypertrophy: novel therapeutic strategies to treat heart failure. *Clin Exp Pharmacol Physiol* **34**(4): 255–62

Mitchell JH, Haskell W, Snell P, Van Camp SP (2005) Task Force 8: classification of sports. *J Am Coll Cardiol* **45**: 1364-7

Papadakis M, Whyte G, Sharma S (2008). Preparticipation screening for cardiovascular abnormalities in young competitive athletes. *BMJ* **337**: 806–11

Pelliccia A, Maron BJ, Spataro A, Proschan MA, Spirito P (1991). The upper limit of physiologic cardiac hypertrophy in highly trained elite athletes. *N Engl J Med* **324**: 295–301

Pelliccia A, Fagard R, Bjørnstad HH et al (2005) Recommendations for competitive sports participation in athletes with cardiovascular disease: a consensus document from the Study Group of Sports Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology. *Eur Heart J* **26**: 1422–45

Pluim BM, Zwinderman AH, van der Laarse A, van der Wall EE (2000) The athlete's heart - A meta-analysis of cardiac structure and function. *Circulation* **101**: 336–44

Teske AJ, Prakken NH, De Boeck BW, Velthuis BK, Doevendans PA, Cramer MJ (2010) Echocardiographic deformation imaging reveals preserved regional systolic function in endurance athletes with left ventricular hypertrophy. *Br J Sports Med* May 10 (Epub ahead of print)

Van Camp SP, Bloor CM, Mueller FO, Cantu RC, Olson HG (1995) Nontraumatic sports death in high school and college athletes. *Med Sci Sports Exerc* **27**: 641-7

Wilson MG, Basavarajaiah S, Whyte GP, Cox S, Loosemore M, Sharma S (2008). Efficacy of personal symptom and family history questionnaires when screening for inherited cardiac pathologies: the role of electrocardiography. *Br J Sports Med* **42**: 207–11