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What may the future hold for sports cardiology?

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The field of sports cardiology has advanced significantly over recent times. It has incorporated clinical and research advances in cardiac imaging, electrophysiology and exercise physiology to enable better diagnostic and therapeutic management of our patients. One important endeavour has been to try and better differentiate athletic cardiac remodelling from inherited cardiomyopathies and other pathologies. Whilst our diagnostic tools have improved, there have also been errors resulting from assumptions that the pathological traits observed in the general population would be generalisable to athletic populations. However, we have learnt that athletes with hypertrophic cardiomyopathy, for example, have many unique features when compared with non-athletic patients with hypertrophic cardiomyopathy. We are learning the limitations of cross-sectional observations and a greater number of prospective studies have been initiated from which should enable us to more confidently interrogate the associations between exercise, cardiac remodelling and clinical outcomes. This review enables some of the world's experts in sports cardiology to reflect on where there is a need for research focus to advance knowledge and clinical care in sports cardiology.

Keywords

Sports • Screening • Athletic remodelling • Athlete's heart • Arrhythmias • Cardiomyopathy

Introduction

Q3 Cardiology is a unique specialty within internal medicine, in that it uses exercise as part of both the diagnosis and treatment of disease. The effect of exercise on cardiovascular function has long been a consideration in medicine but the sub-specialty of sports cardiology represents a relatively new discipline focusing on the clinical issues pertaining to athletes and exercise enthusiasts. The dominant topics of concern have related to the identification of structural heart disease and the management of cardiac arrhythmias, mainly aimed at prevention of sudden cardiac death and deterioration of cardiovascular function. Intense debate has surrounded the issue of pre-participation screening of athletes and this has dominated much of the sports

cardiology agenda over the recent decade. The aim of this commentary is to reflect upon the current topics of interest in sports cardiology and to identify unresolved issues that are likely to receive attention in the decades to come. Q4

What Is an Athlete?

In a field devoted to understanding cardiovascular adaptation and pathology in athletic individuals, it is remarkable that there is no standardised definition of what constitutes an "athlete". The Bethesda guidelines have provided the best current definition of an athlete: "One who participates in an organized team or individual sport that requires regular competition against others as a

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central component, places a high premium on excellence and achievement, and requires some form of systematic (and usually intense) training”[1]. However, the term “athlete” is used extremely broadly in the literature, ranging from amateur exercise enthusiasts through to elite professional sports men and women. There are descriptions of the athlete’s heart, guidelines for athlete evaluation and recommendations for management of the athlete, but there is a conspicuous lack of a definition as to what constitutes an athlete. Beaudry *et al.* have argued that athletic remodelling should be defined relative to fitness given the very strong relationship between objective measures of fitness, such as $VO_2\max$, and the extent of cardiac remodelling [2].

An athlete evolves over time, with periods of more or less training and competition, and with variance in the type of exercise. This is associated with variance of load on the cardiovascular system. The literature needs ways to objectively assess these different loads in different athletes, and in athletes over time. There is still a paucity of information on how information from heart rate and motion sensors, from GPS trackers and other modern technology, can reliably be obtained and processed. At best, we still rely on questionnaires to gauge the number of hours of sports and it remains a major challenge to estimate exercise intensity.

Moreover, when considering the management, there is also a need to consider the setting in which sports are performed given that it can be argued that factors such as playing in a stadium full of supporters may be a setting that is more likely to trigger sudden events such as arrhythmias in predisposed individuals. A single all-encompassing definition may be inadequate given the complexity of the sporting stimuli, but this should not be a barrier to attempt some much-needed standards. For example, oxygen consumption at peak exercise ($VO_2\max$) is an excellent and standardised description of athletic conditioning and could be incorporated as a standard means of describing athletic cohorts that would enable us to compare athletic cohorts between studies.

Pre-participation Screening of Athletes, What Comes Next?

There has been considerable debate about the merits and concerns of including an electrocardiogram (ECG) in pre-participation screening of athletes highlighting the fact that a majority of causes of sudden cardiac death (SCD) in athletes are associated with electrocardiographic abnormalities that may lead to early treatment and preventative strategies [3]. On the other hand, it has been argued that the imperfect specificity of electrocardiographic testing when screening for rare conditions carries risks of harm related to false positives [4–6].

Corrado *et al.* provide the strongest evidence in support of electrocardiographic screening in observing a time-associated reduction in sudden death fatalities over the period in which screening was performed in the Veneto region of Italy [7]. However, there are several potential explanations for this association and the lack of a control population makes it very difficult to confidently conclude that screening saves lives.

When considering that SCD occurs in approximately 1 in 50,000 young athletes, it is extremely unlikely that a prospective randomised study with adequate power will be possible and so the question may remain contentious for many years to come. However, it is worth considering factors unique to the Australian sporting landscape and also recognising the advances that have been made in trying to refine the accuracy of electrocardiographic interpretation in athletes [8,9].

What comes next? We are entering an intriguing era in the science of ECG screening in athletes. Many organisations have adopted policies for recommending ECG screening in athletes including the International Olympic Committee (IOC), the International Football Federation (FIFA), the International Cycling Union (UCI) and most Australian football codes (including Australian Football League [AFL] and Australian Rugby League [ARL]).

Recently, there have been several deaths in high profile athletes who have undergone and been cleared following screening. These tragedies may provide a new opportunity for knowledge advancement in that this evaluation of athletes, sometimes also involving cardiac imaging, may provide some important retrospective insights and better preventative strategies in the future. On the other hand, we may learn that a majority of athletic SCD cases are difficult to anticipate despite modern diagnostics. Indeed, we have to recognise that almost every cardiovascular adaptation to exercise in fact constitutes a pro-arrhythmic potential, questioning even the relevance of the question on what is ‘physiologic’ and what is ‘pathologic’, as shown in Figure 1 [10].

Obtaining evidence for screening in a prospective randomised trial was always going to be challenging but now there may be an opportunity to evaluate the success of screening in retrospect. In other words, by assessing the incidence of sudden death in screened athletes who are subsequently either cleared to play or excluded from sport, we may be able to ascertain its benefits and limitations. We may also learn something about the efficacy of sports exclusion by evaluating the outcomes in those athletes who are excluded from sport due to structural heart disease.

Another future opportunity in the screening process would be to move away from the sole focus on SCD prevention to incorporate more of an educational role. For many young athletes, ‘screening’ represents one of very few interactions with health practitioners. It could be argued that it is an under-utilised opportunity to assess cardiac risk factors and provide information about cardiac alert symptoms, the potential risks of performance-enhancing and recreational drugs.

Pathological Versus Physiological Remodelling

The sports cardiology literature is filled with studies that seek to discriminate healthy physiological athletic remodelling of the myocardium from pathological remodelling due to inherited cardiomyopathies, hypertensive or valvular heart disease. In a recent review, Nakamura and Sadoshima encapsulate the

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