Appropriate interpretation of the athlete’s electrocardiogram saves lives as well as money

Domenico Corrado1* and William J. McKenna2

1Department of Cardiac, Thoracic and Vascular Sciences, University of Padova Medical School, Padova, Italy; and 2The Heart Hospital, University College London, London, UK

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This editorial refers to 'Prevalence of abnormal electrocardiograms in a large, unselected population undergoing pre-participation cardiovascular screening' by A. Pelliccia et al., on page 2006

Long-term Italian experience has provided evidence that systematic pre-participation screening, with 12-lead electrocardiogram (ECG) history and physical examination, is effective in identifying athletes with potentially lethal cardiovascular disease and actually saves lives.1,2 However, concerns have been raised about the cost-effectiveness of screening because of the high level of false-positive results from the ECG.3 This concern arises because (i) ECG changes develop in trained athletes as a consequence of sustained physical exercise ('athlete's heart'); and (ii) there is the misconception that most athletes’ ECG changes overlap significantly with ECG abnormalities seen in the cardiovascular diseases which cause sudden death in the young.3–5 The ECG has therefore been considered to be a poor screening tool for cardiovascular disorders in athletes because of its presumed low specificity. This concept, however, was based on a few studies of small and selected sets of highly trained athletes from a limited number of sports disciplines.5,6

Systematic pre-participation screening in Italy offers the unique opportunity to investigate ECG changes in large cohorts of athletes, engaged in a broad variety of sports activities with different levels of training and fitness.1,2,4,7 The data available define the spectrum of athletes’ ECG patterns, which permits delineation of common, physiological ECG changes and uncommon ECG abnormalities which are usually unrelated to training but associated with an increased cardiovascular risk. This new perspective in the interpretation of an athlete’s ECG raises the need for a revision of accuracy, utility, and cost–benefit analysis of the use of ECG in screening athletes for cardiovascular diseases.

Drawing a line between physiological and potentially malignant ECG changes

In Table 1, athletes’ ECG abnormalities are divided into two groups according to their prevalence, relationship to exercise training, association with an increased cardiovascular risk, and need for further clinical investigation to confirm (or exclude) an underlying cardiovascular disease.

Cardiovascular remodelling in the highly trained athlete is frequently (up to 80%) associated with ECG abnormalities (Group 1) such as sinus bradycardia, first-degree atrioventricular (AV) block, and early repolarization resulting from physiological adaptation of the cardiac autonomic nervous system to training, i.e. increased vagal tone and/or withdrawal of sympathetic activity. Moreover, the ECG of trained athletes often exhibits pure voltage criteria for left ventricular hypertrophy that reflect the physiological left ventricular changes, consisting of increased left ventricular wall thickness and chamber size. Although these ECG changes are ‘abnormal’ in a strict statistical sense, they do not imply the presence of cardiovascular disease or an increase of cardiovascular risk in the athlete.

These ECG changes should be clearly separated from ‘uncommon’ (<5%) ECG patterns (Group 2) such as ST-segment and T-wave repolarization abnormalities, pathological Q waves, intraventricular conduction defects, and ventricular arrhythmias which may be the expression of cardiovascular disorders, notably inherited cardiomyopathies and cardiac ion channel diseases which predispose to sudden arrhythmic death.

The study by Pelliccia et al.7 is an important contribution to our understanding of the athlete’s ECG. The authors report the prevalence of ECG abnormalities in 32 652 amateur Italian athletes undergoing pre-participation screening. ECG changes were present in 3853 (~11.8%). Two-thirds of these changes consisted of ECG patterns commonly regarded as part of the spectrum of benign changes of 'athlete's heart', i.e. prolonged PR interval, early repolarization, incomplete right bundle branch block (RBBB), and increased QRS voltages. Only a minority of screened individuals (~4.0%) showed ECG abnormalities, such as inverted T-waves, intraventricular conduction disturbances, ventricular pre-excitation, and prolonged QTc interval, which required additional testing to exclude an underlying

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* Corresponding author. Tel: +39 049 8212458; fax: +39 049 8212309. E-mail address: domenico.corrado@unipd.it

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Cardiomyopathies have been consistently implicated as the leading cause of sports-related cardiac arrest in young competitive athletes, with hypertrophic cardiomyopathy (HCM) accounting for more than one-third of fatal cases in the USA, and arrhythmogenic right ventricular cardiomyopathy (ARVC) for approximately a quarter of fatal cases in Italy.1,2 The experience of screening for HCM is noteworthy in this regard. The ECG in HCM overlaps marginally with ECG findings in healthy trained athletes. The vast majority of patients with HCM have an abnormal ECG, with repolarization changes, pathological Q waves, and left axis deviation being the most common findings.9–11 An isolated QRS voltage criterion for left ventricular hypertrophy (Sokolow–Lyon or Cornell criteria) is an unusual pattern in patients with HCM in whom pathological hypertrophy is characteristically associated with additional findings such as left atrial overload, left axis deviation, delayed intrinsicoid deflection, T-wave inversion, in inferior, anterior, or lateral leads, and pathological Q waves.1,10–12 Such ECG abnormalities of HCM need to be clearly distinguished from the ECG patterns seen in trained athletes in whom physiological hypertrophy manifests as an isolated increase of QRS amplitude, with right QRS axis deviation, normal atrial and ventricular activation patterns, and normal ST–T repolarization.4–6,12,13 A corollary is that further investigation by echocardiography is not recommended in athletes showing an isolated increase of QRS voltages at pre-participation screening, unless such subjects have other ECG changes suggesting pathological left ventricular hypertrophy, relevant symptoms, abnormal physical examination, or a positive family history for cardiovascular diseases and/or premature sudden cardiac death.

Conversely, signs of potentially lethal organic heart disease may be misinterpreted as normal variants of an athlete’s ECG. For instance, there is a general misconception that inverted T-waves in precordial leads are frequently encountered in trained athletes, being part of the spectrum of cardiovascular adaptive changes to physical exercise.5 In particular, T-wave inversion in right precordial leads (beyond V1) is often dismissed in young competitive athletes as non-specific or as persistence of the juvenile T-wave pattern. Detailed analysis of available data, including those of the study of Pelliccia et al., shows that the prevalence of T-wave inversion in two or more precordial leads did not exceed 4% in large athletic populations (age ≥14 years), regardless of training intensity and duration; moreover, there does not seem to be a greater prevalence in trained athletes compared with sedentary people.7–14 On the other hand, T-wave inversion is an important ECG marker of cardiomyopathies, including HCM, ARVC, dilated cardiomyopathy, cardiac ion channelopathies, ischaemic heart disease, and aortic valve disease.9–11 Of note, right precordial T-wave inversion is present in up to 87% of patients who have ARVC, a recognized leading cause of athletic field sudden death worldwide.1,2,8,14 Since T-wave inversion is rarely observed in the ECG of healthy athletes and, instead, is a common finding in patients with cardiomyopathy, it raises the suspicion of an underlying cardiovascular condition and the athlete should be thoroughly investigated by imaging techniques, exercise test, 24 h Holter monitoring, and, when possible, by genetic testing to exclude a pathological basis. Genotype-phenotype correlation studies in
cardiomyopathy reveal that ECG abnormalities can represent the only sign of disease expression in mutation carriers even in the absence of any other features or before structural changes in the heart can be detected. Accordingly, the perspective that T-wave inversion is due to cardiovascular adaptation in an athlete should only be accepted once inherited forms of cardiovascular disease have been definitively excluded by a comprehensive clinical work-up including investigation of family members.

**Does ECG screening of athletes work?**

In the Italian screening protocol, the ECG is evaluated in light of the athlete's gender, age, race, family history of cardiovascular disease and/or sudden death, clinical symptoms, and physical examination. In asymptomatic athletes with a negative family history, ECG changes due to cardiac adaptation to physical exertion (Group 1) do not cause alarm and allow eligibility to participate in competitive sports without additional evaluation. Further diagnostic work-up is limited to the subset of athletes with ECG changes which potentially reflect underlying heart disease (Group 2), and/or those with a positive medical history or an abnormal physical examination, resulting in a considerable cost savings. This screening algorithm, which has been used for pre-participation evaluation of millions of Italian athletes over a 25-year period, has provided adequate sensitivity and specificity for detection of athletes affected by potentially dangerous cardiomyopathy or arrhythmia at risk of athletic field death and has led to a substantial reduction of mortality of young competitive athletes (by ~90%), mostly by preventing sudden death from cardiomyopathy.1,2,9

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**References**