# The Electrocardiogram in Highly Trained Athletes

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**KEYWORDS**

• Electrocardiography • Athlete's heart • 2010 ESC criteria • Refined criteria
• Ethnicity • Cardiomyopathy • Primary electrical disease

**KEY POINTS**

- The normal electrical manifestations of athletic training reflect an increase in vagal tone and in cardiac chamber size and/or wall thickness. Certain repolarization changes observed in athletes overlap with diseases implicated in sudden cardiac death.
- Electrocardiogram (ECG) interpretation must account for the age, sex, and ethnicity of the athlete as well as the type of sports and level of participation.
- The ECG is just one diagnostic tool for differentiating between physiological adaptation and potentially serious cardiac disorders and should be used in conjunction with a clinical history and physical examination, with further investigations as deemed necessary.
- This article provides a review of the normal ECG patterns associated with athletic training to facilitate the differentiation from electrical patterns suggestive of cardiac diseases implicated in exercise-related sudden cardiac death.

## INTRODUCTION

Participation in regular intensive physical exercise is associated with a constellation of structural and functional changes within the heart that promote increases in cardiac output and/or blood pressure for both burst activities and for prolonged periods. These changes are referred to as the athlete's heart. These physiological changes are commonly manifested on the surface electrocardiogram (ECG). Over the past 3 decades, several studies in large athlete populations have revealed a spectrum of ECG patterns that are considered benign and can be divided broadly into those that reflect autonomic changes (increased vagal tone) and those that reflect an increase in cardiac chamber size and ventricular wall thickness. The magnitude with which these electrical patterns manifest is determined by several demographic factors and the intensity of exercise.

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In some instances, the repolarization changes that occur partly as a result of increased vagal tone may overlap with morphologically mild or incomplete phenotypic expressions of both the cardiomyopathies and ion channel diseases. Marked repolarization changes overlapping with disease processes are usually observed in male endurance athletes and athletes of African/Afro-Caribbean origin. The differentiation of benign physiological adaptation from electrical harbingers of diseases implicated in exercise-related sudden cardiac death is crucial because an erroneous diagnosis either way has potentially serious consequences.

The steady trickle of deaths among athletes and the high visibility of these catastrophes have led several sporting bodies, including the International Olympic Committee, the National Basketball Association, and the Union of European Football Associations, to advocate cardiac screening for their athletes. This practice frequently incorporates a 12-lead ECG hence the interpretation of the ECG is pivotal for the assessment of individuals engaged in competitive sport or high-level routine recreational exercise.

In 2010, the European Society of Cardiology (ESC) published consensus guidelines.[1] ECG changes were divided into 2 groups (**Box 1**) based on findings in more than 33,000 nonselect Italian athletes. Group 1 contains ECG changes that occurred in up to 80% of athletes and were deemed to be normal physiological variants. Anomalies occurring in less than 5% of athletes were categorized as group 2 changes and were considered to warrant further investigation to exclude cardiac disease; specifically cardiomyopathy or ion channel disorders.[1]

Since the publication of the ESC guidelines, several other publications have improved the understanding of the ECGs of athletes and stimulated further modifications of these recommendations. This article provides a critical appraisal of the ECGs of athletes using the ESC 2010 guidelines as the current gold standard.

## GROUP 1 EUROPEAN SOCIETY OF CARDIOLOGY CRITERIA

Group 1 changes include sinus bradycardia, sinus arrhythmia, first degree atrioventricular (AV) block, and early repolarization consisting of J-point elevation, ST segment elevation, and tall T waves. Most group 1 changes are attributable to increased vagal tone. Sinus bradycardia (heart rate <60 beats per minute [bpm]) is common and observed in more than 80% of athletes. Less than 5% have a heart rate less than

**Box 1**
**ESC 2010 criteria for interpretation of an athlete's ECG**

| Group 1 | Group 2 |
|---|---|
| Sinus bradycardia | T-wave inversion |
| First-degree atrioventricular block | ST depression |
| Early repolarization | Pathologic Q waves |
| Isolated QRS voltage criteria for left ventricular hypertrophy | Left atrial enlargement |
| Incomplete right bundle branch block | Left axis deviation/left anterior hemiblock |
| — | Right axis deviation/left posterior hemiblock |
| — | Right ventricular hypertrophy |
| — | Complete left bundle branch block/right bundle branch block |
| — | Long or short QT interval |
| — | Brugada-like early repolarization |
| — | Ventricular pre-excitation |