Electrocardiographic interpretation in athletes: the 'Seattle Criteria'

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ABSTRACT

Sudden cardiac death (SCD) is the leading cause of death in athletes during sport. Whether obtained for screening or diagnostic purposes, an ECG increases the ability to detect underlying cardiovascular conditions that may increase the risk for SCD. In most countries, there is a shortage of physician expertise in the interpretation of an athlete's ECG. A critical need exists for physician education in modern ECG interpretation that distinguishes normal physiological adaptations in athletes from abnormal findings suggestive of pathology. On 13–14 February 2012, an international group of experts in sports cardiology and sports medicine convened in Seattle, Washington, to define contemporary standards for ECG interpretation in athletes. The objective of the meeting was to develop a comprehensive training resource to help physicians distinguish normal ECG alterations in athletes from abnormal ECG findings that require additional evaluation for conditions associated with SCD.

INTRODUCTION

Cardiovascular-related sudden death is the leading cause of mortality in athletes during sport.[1 2] The majority of disorders associated with increased risk of sudden cardiac death (SCD), such as cardiomyopathies and primary electrical diseases, are suggested by abnormal findings present on a 12-lead ECG. ECG interpretation in athletes requires careful analysis to properly distinguish physiological changes related to athletic training from findings suggestive of an underlying pathological condition. Whether used for the diagnostic evaluation of cardiovascular-related symptoms, a family history of inheritable cardiac disease or premature SCD, or for screening of asymptomatic athletes, ECG interpretation is an important skill for physicians involved in the cardiovascular care of athletes.

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DISTINGUISHING NORMAL FROM ABNORMAL

A challenge in the interpretation of an athlete's ECG is the ability to accurately differentiate findings suggestive of a potentially lethal cardiovascular disorder from benign physiological adaptations occurring as the result of regular, intense training (ie, athlete's heart). Several reports have outlined contemporary ECG criteria intended to distinguish normal ECG findings in athletes from ECG abnormalities requiring additional evaluation.[3–8] Despite the publication of these consensus guidelines, most sports medicine and cardiology training programmes lack a standard educational curriculum on ECG interpretation in athletes.

THE IMPACT OF STANDARDISED CRITERIA

Studies demonstrate that without further education the ability of many physicians to accurately interpret an athlete's ECG is relatively poor and may lead to an unacceptable rate of false-positive interpretations and unnecessary secondary evaluations.[9 10] However, providing physicians standardised criteria with which to evaluate an ECG considerably improves accuracy.[10] In a study involving physicians across different specialties, use of a simple two-page criteria tool to guide ECG interpretation significantly improved accuracy to distinguish normal from abnormal findings, even in physicians with little or no experience.[10] Therefore, physician education in ECG interpretation is feasible and accompanied by meaningful improvements in accuracy when a reference standard is used to assist interpretation. Further education is needed to produce a larger physician infrastructure that is skilled and capable of accurate ECG interpretation in athletes.

SUMMIT ON ECG INTERPRETATION IN ATHLETES

On 13–14 February 2012, the American Medical Society for Sports Medicine (AMSSM) co-sponsored by the FIFA Medical Assessment and Research Center (F-MARC) held a 'Summit on Electrocardiogram Interpretation in Athletes' in Seattle, Washington. Partnering medical societies included the European Society of Cardiology (ESC) Sports Cardiology Subsection and the Pediatric & Congenital Electrophysiology Society (PACES), as well as other leading cardiologists on ECG

interpretation in athletes from the USA, Europe and around the world. The goals of the summit meeting were to:

1. define ECG interpretation standards to help physicians distinguish normal ECG alterations in athletes from abnormal ECG findings that require additional evaluation for conditions associated with SCD;
2. outline recommendations for the initial evaluation of ECG abnormalities suggestive of a pathological cardiovascular disorder; and
3. assemble this information into a comprehensive resource and online training course targeted for physicians around the world to gain expertise and competence in ECG interpretation.

The consensus recommendations developed are presented in three papers:

4. *Normal Electrocardiographic Findings: Recognizing Physiologic Adaptations in Athletes*[11]
5. *Abnormal Electrocardiographic Findings in Athletes: Recognizing Changes Suggestive of Cardiomyopathy*[12]
6. *Abnormal Electrocardiographic Findings in Athletes: Recognizing Changes Suggestive of Primary Electrical Disease*[13]

Box 1 summarises a list of normal ECG findings in athletes that are considered physiological adaptations to regular exercise and do not require further evaluation. Table 1 summarises a list of abnormal ECG findings unrelated to athletic training that may suggest the presence of a pathological cardiac disorder and should trigger additional evaluation in an athlete.

ONLINE E-LEARNING ECG TRAINING MODULE—FREE!

The Seattle Criteria will be used to develop a comprehensive online training module for physicians to acquire a common foundation in ECG interpretation in athletes. This state of the art E-learning resource provides additional ECG examples, figures and explanations, and is prepared in a user friendly educational format to optimise learning. This online training module is accessible at no cost to any physician world-wide at: http://learning.bmj.com/ECGathlete

Box 1 Normal ECG findings in athletes

1. Sinus bradycardia (≥ 30 bpm)
2. Sinus arrhythmia
3. Ectopic atrial rhythm
4. Junctional escape rhythm
5. 1° AV block (PR interval > 200 ms)
6. Mobitz Type I (Wenckebach) 2° AV block
7. Incomplete RBBB
8. Isolated QRS voltage criteria for LVH
   - *Except*: QRS voltage criteria for LVH occurring with any non-voltage criteria for LVH such as left atrial enlargement, left axis deviation, ST segment depression, T-wave inversion or pathological Q waves
9. Early repolarisation (ST elevation, J-point elevation, J-waves or terminal QRS slurring)
10. Convex ('domed') ST segment elevation combined with T-wave inversion in leads V1–V4 in black/African athletes

These common training-related ECG alterations are physiological adaptations to regular exercise, considered normal variants in athletes and do not require further evaluation in asymptomatic athletes.

AV, atrioventricular; bpm, beats per minute; LVH, left ventricular hypertrophy; ms, milliseconds; RBBB, right bundle branch block.

Table 1 Abnormal ECG findings in athletes

Abnormal ECG finding	Definition
T-wave inversion	>1 mm in depth in two or more leads V2–V6, II and aVF, or I and aVL (excludes III, aVR and V1)
ST segment depression	≥0.5 mm in depth in two or more leads
Pathologic Q waves	>3 mm in depth or >40 ms in duration in two or more leads (except for III and aVR)
Complete left bundle branch block	QRS ≥120 ms, predominantly negative QRS complex in lead V1 (QS or rS), and upright monophasic R wave in leads I and V6
Intraventricular conduction delay	Any QRS duration ≥140 ms
Left axis deviation	−30° to −90°
Left atrial enlargement	Prolonged P wave duration of >120 ms in leads I or II with negative portion of the P wave ≥1 mm in depth and ≥40 ms in duration in lead V1
Right ventricular hypertrophy pattern	R–V1+S–V5>10.5 mm *AND* right axis deviation >120°
Ventricular pre-excitation	PR interval <120 ms with a delta wave (slurred upstroke in the QRS complex) and wide QRS (>120 ms)
Long QT interval*	QTc≥470 ms (male) QTc≥480 ms (female) QTc≥500 ms (marked QT prolongation)
Short QT interval*	QTc≤320 ms
Brugada-like ECG pattern	High take-off and downsloping ST segment elevation followed by a negative T wave in ≥2 leads in V1–V3
Profound sinus bradycardia	<30 BPM or sinus pauses ≥ 3 s
Atrial tachyarrhythmias	Supraventricular tachycardia, atrial-fibrillation, atrial-flutter
Premature ventricular contractions	≥2 PVCs per 10 s tracing
Ventricular arrhythmias	Couplets, triplets and non-sustained ventricular tachycardia

Note: These ECG findings are unrelated to regular training or expected physiological adaptation to exercise, may suggest the presence of pathological cardiovascular disease, and require further diagnostic evaluation.
*The QT interval corrected for heart rate is ideally measured with heart rates of 60–90 bpm. Consider repeating the ECG after mild aerobic activity for borderline or abnormal QTc values with a heart rate <50 bpm.

LIMITATIONS OF THE SEATTLE CRITERIA

While the ECG increases the ability to detect underlying cardiovascular conditions that place athletes at increased risk, ECG as a diagnostic tool has limitations in both sensitivity and specificity. Even if properly interpreted, an ECG will not detect all conditions predisposing to SCD. In addition, the true prevalence of specific ECG parameters in athletes and in diseases that predispose to SCD is often unknown and requires further study. The Seattle Criteria were developed with thoughtful attention to balance sensitivity (disease detection) and specificity (false-positives), while maintaining a clear and usable checklist of findings to guide ECG interpretation for physicians, including new learners.

The criteria define ECG findings that warrant further cardiovascular evaluation for disorders that predispose to SCD. The criteria were developed with consideration of ECG interpretation in the context of an asymptomatic athlete age 14–35. An athlete is defined as an individual who engages in regular exercise or training for sport or general physical fitness, typically with a goal of improving performance. In the presence of

personal cardiac symptoms or a family history that is positive for genetic cardiovascular disease or premature SCD, the criteria may require modification. Physicians also may choose to deviate from consensus standards based on their experience or practice setting.

The evaluation of ECG abnormalities is performed ideally in consultation with a specialist with knowledge and experience in athlete's heart and disorders associated with SCD in young athletes. As new scientific data become available, revision of the criteria may further improve the accuracy of ECG interpretation within the athletic population.

CONCLUSIONS

Prevention of SCD in athletes remains a highly visible topic in sports medicine and cardiology. Cardiac adaptation and remodelling from regular athletic training produces common ECG alterations that could be mistaken as abnormal. Whether performed for screening or diagnostic purposes as part of the cardiac evaluation in athletes, it is critical that physicians responsible for the cardiovascular care of athletes be guided by ECG interpretation standards that improve disease detection and limit false-positive results. The ECG interpretation guidelines presented and the online training programme serve as an important foundation for improving the quality of ECG interpretations and the cardiovascular care of athletes.

Additional resources

For a free online training module on ECG interpretation in athletes, please visit: http://learning.bmj.com/ECGathlete. For the November 2012 BJSM supplement on "Advances in Sports Cardiology," please visit: http://bjsm.bmj.com/content/46/Suppl_1.toc

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