Refining Electrocardiography Interpretation
Criteria in Elite Athletes

Ahmed Tageldien Abdellah

MD, FRSM-London, EBAC-UK
Cardiology Department
Suez Canal University
Refining ECG Criteria in Athletes

- Why Should We Screen Athletes?
- What & How To Screen?
- ECG Abnormalities In Athletes
- When To Raise Red Flags?
- Value Of Screening In Practice
- Dilemma

Sports Classification based on Static and Dynamic Components
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Athletes and Sudden Cardiac Death

- SCD is the leading cause of mortality in young athletes.
- Majorly due to diverse inherited & congenital cardiac diseases.
- Screening is necessary to identify those at high risk, thus saving lives.
- Competitive athletes have increased risk of SCD (2-2.8 fold).
Athletes and Sudden Cardiac Death

- Prevalence of CV diseases predisposing to SCD in athletes ranges 0.2 - 0.7%.
- Mechanism of SCD is usually ventricular arrhythmia.
- How: Exercise induced catecholamine surge acting on arrhythmogenic substrate.
- Precipitators: Dehydration, pyrexia, electrolyte imbalance & platelet aggregation.

Athletes and Sudden Cardiac Death

Competitive Athletes are 2.5 fold greater risk for SCD in comparison with their age & gender matched counterparts.
Recipe for Arrhythmia

- Platelet activation
- Infection
- Fever
- Trauma
- Dehydration
- Electrolyte imbalance
- Drugs
- Neurohomonal

Common Causes of SCD in Athletes
Causes Of Sudden Cardiac Death in Athletes

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The 12-Element AHA Recommendations for Pre-participation Cardiovascular Screening of Competitive Athletes

**Personal history**
1. Exertional chest pain/discomfort
2. Unexplained syncope/near-syncope
3. Excessive exertional and unexplained dyspnea/fatigue, associated with exercise
4. Prior recognition of a heart murmur
5. Elevated systemic blood pressure

**Family history**
6. Premature death (sudden and unexpected) <50 yr-old due to heart disease
7. Disability from heart disease in a close relative <50 years of age
8. HOCM, DCMP, long-QT syndrome, Marfan syndrome, or clinically important arrhythmias

**Physical examination**
9. Heart murmur
10. Femoral pulses (to exclude aortic coarctation)
11. Physical stigmata of Marfan syndrome
12. Brachial artery blood pressure (sitting position)

ESC Screening Protocol for Competitive Athletes

- Echo.
- Holter
- Stress test
- MRI
- EPS
- Genetic
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Electrical Changes in Athletes

- **What**: ST-T changes, channelopathies, bradycardia, ERP & hypertrophy.

- **Why**: Inherited, Congenital, ANS conditioning: increased vagal tone & sympathetic withdrawal/activation.

- **Cellular changes**: Functional down regulation of K currents & aberrant Ca handling
  - Frequent spontaneous activity
  - Prolongation of AP duration

- These changes could eventually lead to **ventricular arrhythmia**
**The ESC criteria for ECG findings in athletes**

<table>
<thead>
<tr>
<th>Group 1: Common and Training-Related Electrocardiographic Changes</th>
<th>Group 2: Uncommon and Training-Unrelated Electrocardiographic Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus bradycardia</td>
<td>T-wave inversion</td>
</tr>
<tr>
<td>First-degree atroventricular block</td>
<td>ST-segment depression</td>
</tr>
<tr>
<td>Incomplete right bundle branch block</td>
<td>Pathological Q waves</td>
</tr>
<tr>
<td>Early repolarization</td>
<td>Left atrial enlargement</td>
</tr>
<tr>
<td>Isolated QRS voltage criteria for left ventricular hypertrophy</td>
<td>Right atrial enlargement</td>
</tr>
<tr>
<td>Left axis deviation</td>
<td></td>
</tr>
<tr>
<td>Right axis deviation</td>
<td></td>
</tr>
<tr>
<td>Right ventricular hypertrophy</td>
<td></td>
</tr>
<tr>
<td>Ventricular pre-excitation</td>
<td></td>
</tr>
<tr>
<td>Left bundle branch block</td>
<td></td>
</tr>
<tr>
<td>Right bundle branch block</td>
<td></td>
</tr>
<tr>
<td>Long QTc interval (&gt;440 ms in males; &gt;460 ms in females)</td>
<td></td>
</tr>
<tr>
<td>Short QTc interval (&lt;380 ms)</td>
<td></td>
</tr>
<tr>
<td>Brugada-like early repolarization</td>
<td></td>
</tr>
</tbody>
</table>

**The American (Seattle) criteria for Normal ECG findings in athletes**

<table>
<thead>
<tr>
<th>Normal ECG criteria</th>
</tr>
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<tbody>
<tr>
<td>Sinus bradycardia &lt; 30 bpm</td>
</tr>
<tr>
<td>Sinus arrhythmia</td>
</tr>
<tr>
<td>Ectopic atrial rhythm</td>
</tr>
<tr>
<td>Junctional escape rhythm</td>
</tr>
<tr>
<td>First-degree AV block (PR &gt; 200 ms)</td>
</tr>
<tr>
<td>Mobitz I second-degree AV block</td>
</tr>
<tr>
<td>Incomplete right bundle branch block</td>
</tr>
<tr>
<td>Isolated voltage criteria for LVH (absence of left atrial enlargement, left axis deviation, ST depression, T-wave inversion, pathologic Q waves)</td>
</tr>
<tr>
<td>Early repolarization (ST elevation with T-wave inversion in V1-V4)</td>
</tr>
</tbody>
</table>
The American (Seattle) criteria for Abnormal ECG findings in athletes

<table>
<thead>
<tr>
<th>Criteria</th>
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<tbody>
<tr>
<td>T-wave inversion (in two or more leads V2-V6, II, aVF, or I and aVL)</td>
</tr>
<tr>
<td>ST depression (&gt; 0.5 mm in two or more leads)</td>
</tr>
<tr>
<td>Sinus tachycardia</td>
</tr>
<tr>
<td>Pathologic Q waves (&gt; 3 mm in depth or &gt; 4 msec in duration in two or more leads except III and aVR)</td>
</tr>
<tr>
<td>Left bundle branch block</td>
</tr>
<tr>
<td>Left axis deviation (-30° to -90°)</td>
</tr>
<tr>
<td>Left atrial enlargement</td>
</tr>
<tr>
<td>Right ventricular hypertrophy (RV1 + SV5 &gt; 10.5 mm and right axis deviation)</td>
</tr>
<tr>
<td>Ventricular pre-excitation</td>
</tr>
<tr>
<td>Brugada-like ECG pattern</td>
</tr>
<tr>
<td>Sinus bradycardia &lt; 30 bpm</td>
</tr>
<tr>
<td>PVCs (&gt; two PVCs per 10-second tracing or nonsustained ventricular tachycardia)</td>
</tr>
</tbody>
</table>

Caveats in the ECG screening Criteria

- High false positive rate (10-20%)
- Disqualifying healthy athletes from sports participation
- Appeal proposals
- Misleading the epidemiology of CV conditions affecting athletes
- Cost effectiveness
Refined American criteria for Abnormal ECG findings in athletes

Training related normal findings
- Sinus bradycardia
- First degree AV block
- Incomplete RBBB
- Early repolarisation
- Isolated QRS voltage criteria for LVH

Borderline (minor abnormal) findings
- Left Atrial enlargement
- Right atrial enlargement
- Left axis deviation
- Right axis deviation
- Right ventricular hypertrophy
- T-wave inversion in leads V1-V4 in Black athletes

Training unrelated abnormal findings
- ST segment depression
- Pathological Q waves
- T-wave inversions beyond V1 in Caucasian athletes; beyond V4 in Black athletes
- Complete LBBB or RBBB
- QTc ≥ 470ms
- Brugada like pattern
- Atrial or ventricular arrhythmias
- ≥ 2 PVCs per 10 sec

If found in isolation considered normal
If 2 or more patterns present considered abnormal

Comparison of ECG interpretation in screening athletes

<table>
<thead>
<tr>
<th>Condition</th>
<th>Combined (n=2491)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence of an abnormal ECG using ESC recommendations</td>
<td>555 (22.3%)</td>
</tr>
<tr>
<td>Prevalence of an abnormal ECG using Seattle Criteria</td>
<td>289 (11.6%)</td>
</tr>
<tr>
<td>Prevalence of an abnormal ECG using Refined Criteria</td>
<td>132 (5.3%)</td>
</tr>
<tr>
<td>Number of identified conditions associated with SCD</td>
<td>10 (7 HCM; 3 WPW)</td>
</tr>
<tr>
<td>FPR when using ESC recommendations</td>
<td>21.9%</td>
</tr>
<tr>
<td>FPR when using Seattle Criteria</td>
<td>11.2%</td>
</tr>
<tr>
<td>FPR when using Refined Criteria</td>
<td>4.3%</td>
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### ECG Abnormalities

<table>
<thead>
<tr>
<th>ECG Abnormalities</th>
<th>36th Bethesda Conference (ACC/AHA)</th>
<th>ESC</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPW</td>
<td>Athletes without structural heart disease, without a history of palpitations, or without tachycardia can participate in all competitive sports.</td>
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<tr>
<td></td>
<td>In athletes with symptoms, EP study and ablation are recommended. Return to competitive sports is allowed after corrective ablation, provided that the ECG has normalized.</td>
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<tr>
<td>LQTS</td>
<td>Exclude any athlete with a previous cardiac arrest or syncopal episode from competitive sports.</td>
<td>Exclude any athlete with a clinical or genotype diagnosis from competitive sports.</td>
</tr>
<tr>
<td></td>
<td>Asymptomatic patients restricted to competitive low-intensity sports.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Genotype-positive/phenotype-negative athletes may still compete.</td>
<td></td>
</tr>
<tr>
<td>Brugada Syndrome</td>
<td>Exclude from all competitive sports except those of low intensity.</td>
<td>Exclude from all competitive sports.</td>
</tr>
<tr>
<td>ECG Abnormalities</td>
<td>36th Bethesda Conference (ACC/AHA)</td>
<td>ESC</td>
</tr>
<tr>
<td>-------------------</td>
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</tr>
<tr>
<td>CPVT</td>
<td>Exclude all patients with a clinical diagnosis from competitive sports.</td>
<td>Exclude all patients with a clinical diagnosis from competitive sports.</td>
</tr>
<tr>
<td></td>
<td>Genotype-positive/phenotype-negative patients may still compete in low-intensity sports.</td>
<td>Genotype-positive/phenotype-negative patients are also excluded.</td>
</tr>
<tr>
<td>ARVC</td>
<td>Exclude athletes with a probable or definitive diagnosis from competitive sports.</td>
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</tr>
</tbody>
</table>

**Refined American criteria for Abnormal ECG findings in athletes**

- **Sinus bradycardia**
- **First degree AV block**
- **Incomplete RBBB**
- **Early repolarisation**
- **Isolated QRS voltage criteria for LVH**
- **Left Atrial enlargement**
- **Right atrial enlargement**
- **Left axis deviation**
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- **Right ventricular hypertrophy**
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**ECG Screening for Competitive Athletes:**

**Meta-analysis**

- Meta-analysis of 15 articles reporting on 47,137 athletes.

- CV conditions detected were 160 (0.3%) or (1 in 294)

- WPW was the highest prevalence (67/160, 42%)

- Sensitivity and specificity: ECG 94%/93%, history 20%/94% & PE 9%/97%

- False positive rate: ECG (6%), history (8%) & physical exam (10%)

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**ECG at initial evaluation**

![ECG Images]
ECG at Holter Monitoring

Annual incidence rate of SCD/100,000 person, among screened competitive athletes and unscreened non-athletes 12–35 years of age in the Veneto in Italy, 1979 - 2004.

The incidence of SCD declined by 89% in screened athletes (P <0.001). However, the incidence of SCD did not change over that time in unscreened non-athletes.
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➢ ECG Abnormalities In Athletes

➢ When To Raise Red Flags?

➢ Value Of Screening In Practice

➢ Dilemma

Dilemma!

• Real prevalence & causes of SCD in athletes

• Normal, adaptive and maladaptive variants of CV response in athletes

• Pre-participation screening programs standardization

• ‘Certainly’ vs. ‘not sure’ findings

• False positive & false negative results, poly-investigations

• When to re-engage in competitive sports

• Cost-effectiveness
**Take Home Message**

- SCD in athletes is 2.8 fold more than non-athletes counterparts.
- Victims of SCD are often entirely asymptomatic before their initial presentation and demonstrate only subtle abnormalities on investigation.
- Pre-participation screening of competitive athletes is a preventive strategy that should be implemented routinely and effectively.
- This includes: History, Examination & ECG as initial step, followed by Echocardiogram and other cardiovascular investigations if needed.

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**Take Home Message**

- The most effective strategy for screening for CV disease in athletes is ECG
- The refined ECG criteria improved the detection of true positive athlete cases
- ECG is 5 times > sensitive than history, 10 times > sensitive than physical exam
- ECG has higher positive & lower negative likelihood & lower false positive rate
- 12-lead ECG should be considered in standard screening for athletes while the use of history and physical examination alone should be re evaluated
Suggested Reading

✓ Machado M, Vaz Silva M. Benign and pathological electrocardiographic changes in athletes. Rev Port Cardiol. 2015 Dec;34 (12):753-70.