How to read the ECG in athletes:
distinguishing normal from abnormal

Antonio Pelliccia, MD
Institute of Sport Medicine and Science
www.antoniopelliccia.it
Cardiac adaptations to Rowing

Vagotonia
- Sinus bradycardia
- Sinus arrhythmia
- First and second degree AVB
- Early repolarization

Increased chamber size
- Left ventricular enlargement and hypertrophy
- Right ventricular enlargement
- Left and right atrial enlargement
- Right atrial enlargement
Recommendations for interpretation of 12-lead electrocardiograms in athletes: the ‘Seattle Criteria’


This document was developed in collaboration between the American Medical Society for Sports Medicine (AMSSM), the Section on Sports Cardiology of the European Association for Cardiovascular Prevention and Rehabilitation (EACPR), a registered branch of the European Society of Cardiology (ESC), the FIFA Medical Assessment and Research Center (F-MARC), and the Pediatric & Congenital Electrophysiology Society (PACES).
ECG abnormalities in the athlete

(Group 1)
common (up to 80%)
- Sinus bradycardia
- First degree AV block
- Notched QRS in V1 or incomplete RBBB
- Early repolarization
- Isolated QRS voltage criteria for left ventricular hypertrophy

(Group 2)
Uncommon (< 5%)
- T-wave inversion
- ST-segment depression
- Pathological Q waves
- Left atrial enlargement
- Left axis deviation/left anterior hemiblock
- Right axis deviation/left posterior hemiblock
- Right ventricular hypertrophy
- Complete LBBB or RBBB
- Long or short QT interval
- Brugada-like early repolarization
- Ventricular arrhythmias
Sinus Bradycardia
&
Sinus Arrhythmia
ECG demonstrates sinus bradycardia with a heart rate of 40 bpm and P-wave axis of 17 degrees (arrows). The 3 required features of sinus bradycardia include: 1) P-wave before every QRS complex, 2) QRS after every P-wave, and 3) normal P-wave axis (frontal plane 0-90 degrees).
Simple method to calculate heart rate
Sinus Arrhythmia

ECG demonstrates sinus arrhythmia. Note the irregular heart rate that varies with respiration. The P-waves are upright in leads I and aVF (frontal plane) suggesting a sinus origin.
1\textsuperscript{st} Degree AV Block
&
2\textsuperscript{nd} Degree AV Block, Mobitz\textsuperscript{Type I}
1° AV block (PR interval > 200 ms) /2

The PR interval is measured from the beginning of the P-wave to the beginning of the R-wave. In this ECG tracing, the PR interval is constant from beat to beat and measures 300 ms.
2nd degree AV block, Mobitz Type I (Wenckebach) is demonstrated by progressively longer PR intervals until a dropped QRS. The PR interval on the first three beats are 140 ms, 190 ms, and 200 ms, respectively. The fourth P wave has no QRS complex following it. The PR interval after the fifth P wave is 140 ms again.
A 19-year old asymptomatic rower demonstrating sinus bradycardia with 2nd degree AV Block, Mobitz type I.
Incomplete Right Bundle Branch Block
Incomplete Right Bundle Branch Block

ECG demonstrates incomplete right bundle branch block (IRBBB) with rSR’ pattern in V1 and QRS duration of < 120 ms. IRBBB is a common and normal finding in athletes and does not require additional evaluation.
Panel A. Brugada-ECG pattern mimicking IRBBB. The “J-wave” (arrows) of Brugada-ECG is confined to right precordial leads (V1 and V2) without reciprocal “S-wave” (of comparable voltage and duration) in leads I and V6 (arrowheads).

Panel B. IRBBB in a trained athlete. The RV conduction interval is mildly prolonged (QRS duration = 115 ms) with a typical rSR’ pattern in V1 (arrow). Note also the reciprocal “S-wave” in V6 (arrow).
Increased R/S-wave Voltages
(Criteria for Left Ventricular Hypertrophy)
Isolated Increased QRS Voltage

ECG from a male rower demonstrating isolated increased QRS voltage (S-V1 + R-V5 = 40 mm) without other abnormalities.
ECG from a 19 year old asymptomatic rower demonstrating sinus bradycardia (42 bpm) and voltage criteria for LVH. Increased QRS amplitude without other ECG abnormalities is a common finding in trained athletes and does not require additional testing.
ECG demonstrating isolated increased QRS voltage (S-V1 17 + R-V5 33 = 50 mm) in an 18 year old asymptomatic male. Note the absence of ST depression, T-wave inversion, pathologic Q waves, left atrial enlargement, or left axis deviation.
Increased QRS voltages in athletes

- A pure increase of QRS voltages accounts for about 60% of all the ECG abnormalities in athletes and occurs in the absence of underlying cardiac pathology.
- Major determinants for LVH pattern are: the extent of morphologic LV enlargement/hypertrophy, the endurance type of sport (cycling, cross-country skiing, rowing, canoeing) and the male gender.
Prevalence of criteria for LVH in relation to sport
Prevalence of criteria for LVH according to gender

- **Distinctly Increased**
  - Men: 17%
  - Women: 8%
  - P < 0.001

- **Mildly Increased**
  - Men: 28%
  - Women: 14%
  - P < 0.001

- **Normal or Minor Alterations**
  - Men: 55%
  - Women: 78%
  - P < 0.001
### Increased QRS voltages (LVH) in athletes

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Percentage</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Adult Caucasian Athletes</td>
<td>23 %</td>
<td>1 Pelliccia et al. 2000, 2011</td>
</tr>
<tr>
<td>Adult Afro-Caribbean Athletes</td>
<td>23 %</td>
<td>2 Sharma 1999, 2011</td>
</tr>
<tr>
<td>Young Caucasian Athletes</td>
<td>45 %</td>
<td>3</td>
</tr>
<tr>
<td>Adolescent African Athletes</td>
<td>89%</td>
<td>4</td>
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</tbody>
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Early Repolarization
Classic and new definitions of early repolarization. (STE= ST elevation)
Patterns of ST-Segment elevation (1)

- Elevated J point, upward concavity of the ST-segment with peaked and tall terminal T-wave
- Usually, $V_3$ to $V_5$
- Present in 50-60% of elite Caucasian athletes
ECG shows early repolarization with ST elevation in all leads in an asymptomatic young athlete.
Early Repolarization in Black/African Athletes: Normal Variant
Patterns of ST-Segment elevation (2)

- Elevated ST-segment, convex on the top (“domed”), with small/indistinct, terminal negative T-wave
- Usually, located in leads $V_2$ to $V_4$
- Present in $<20\%$ of elite Caucasian athletes
- More common in Afro-Caribbean (30-50%)
A 21-year old black/African soccer player with sinus bradycardia, 1st degree AV Block, early repolarization in leads II, V2-V6 (arrows), and T-wave inversion in leads V1-V3 (circles). ‘Domed’ ST segment elevation followed by T wave inversion in the anterior precordial leads in black/African athletes is considered a normal finding.
Patterns of ST-Segment elevation (3)

- Mixed patterns, or a more unusual ST-segment and T wave morphology
- Less than 20% of elite athletes
# Prevalence of Early Repolarization Pattern

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<table>
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<tr>
<td><strong>General Population</strong></td>
<td>1-2 %</td>
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<tr>
<td><strong>Elite Caucasian Athletes</strong></td>
<td>14 -26 %</td>
</tr>
<tr>
<td><strong>Elite Afro-Caribbean Athletes</strong></td>
<td>63 %</td>
</tr>
<tr>
<td><strong>Adolescent Caucasian Athletes</strong></td>
<td>44-56 %</td>
</tr>
<tr>
<td><strong>Adolescent African Athletes</strong></td>
<td>91 %</td>
</tr>
</tbody>
</table>

*from: Pelliccia et al., Circulation 2000; Papadakis et al. Eur Heart J, 2011 and Di Paolo JACC 2012:*
Summary Examples:
Normal ECG Findings in Athletes
A 19-year old asymptomatic soccer player demonstrating sinus arrhythmia with 1st degree AV block (PR interval > 200 ms) and early repolarization (arrows).
A 29-year old asymptomatic soccer player demonstrating sinus bradycardia, early repolarization (ST elevation) in leads I, II, aVF, V2-V6 (arrows), and voltage criteria for LVH.
A 24 year old athlete with sinus bradycardia (45 bpm), early repolarization in I, II, V2-V6 (red arrows), voltage criteria for LVH, and peaked T-waves (circles). These are common, training-related ECG changes in athletes.
The abnormal ECGs in athletes
ECG abnormalities in the athlete

(Group 1) Common (up to 80%)
- Sinus bradycardia
- First degree AV block
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- Isolated QRS voltage criteria for left ventricular hypertrophy

(Group 2) Uncommon (< 5%)
- T-wave inversion
- ST-segment depression
- Pathological Q waves
- Left atrial enlargement
- Left axis deviation/left anterior hemiblock
- Right axis deviation/left posterior hemiblock
- Right ventricular hypertrophy
- Complete LBBB or RBBB
- Long or short QT interval
- Brugada-like early repolarization
- Ventricular arrhythmias
ECG abnormalities in HCM

- Diffuse T-wave inversion in precordial (V_{4-6}) and standard (II,III,VF) leads (60%)
- Pathologic Q-waves (30%)
- Left atrial enlargement (25%)
- Conduction abnormalities (25%)
- Left axis deviation (5%)
- Isolated increase in R/S voltages or Normal Patterns (5%)
Pathologic T-wave Inversion in Black/African Athletes

ECG shows pathologic T-wave inversion in the lateral leads. T-wave inversion in V5-V6 is always an abnormal finding and requires additional testing to rule out cardiomyopathy.
- Inverted T-wave in anterior precordial leads $V_1$ to $V_3$ ($V_4$) in individuals >14 yrs (without RBBB)
- Epsilon wave
- NSVT with LBB and superior axis configuration
- Frequent (>500/24 h) PVBs with LLB configuration
ARVC-Pattern ECG

ECG shows pathologic T-wave inversion in V1-V3. Note the isoelectric ST segment. The absence of ST segment elevation prior to T-wave inversion makes this ECG abnormal. Additional testing is required to rule out ARVC.
Prevalence of T-wave inversion in CMPs

V1
V2
V3
V4

up to 80%

40 to 60%
The abnormal ECG precedes LVH in HCM

Abnormal findings
- Genotype anomalies
- Abnormal ECG
- LV Hypertrophy

Sudden death can occur at any time!
Brugada syndrome

- Genetic disease with autosomal dominant pattern of inheritance
- Affects the transmembranic ion channel exchange, in the absence of structural cardiac abnormalities
- 18-30% of cases associated with Gene SCN5A (deficit of Na+ conductance);
- Electrical abnormalities present in ECG leads exploring the RV outflow tract ($V_2, V_3$);
Brugada type 1

Early repolarization in trained athletes
Measurement of QT interval

- The QT interval = interval between onset of QRS-complex and the end of T-wave
- Lead II (of a 12-lead ECG) is the best lead
- Measurements performed by hand
- Traces with stable heart rate and constant RR intervals
- At least three separate measurements
Known causes of SCD

Detectable at screening about 60% of all causes
Annual Incidence Rates of Sudden Cardiovascular Death in Screened Competitive Athletes and Unscreened Nonathletes Aged 12 to 35 Years in the Veneto Region of Italy (1979-2004)

P for trend <0.001

Corrado et al JAMA 2006;296:1593-1601
ESC Report

Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol

Consensus Statement of the Study Group of Sport Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology

Domenico Corrado¹*, Antonio Pelliccia², Hans Halvor Bjørnstad³, Luc Vanhees⁴, Alessandro Biffi², Mats Borjesson⁵, Nicole Panhuyzen-Goedkoop⁶, Asterios Deligiannis⁷, Erik Solberg⁸, Dorian Dugmore⁹, Klaus P. Mellwig¹⁰, Deodato Assanelli¹¹, Pietro Delise¹², Frank van-Buuren¹⁰, Aris Anastasakis¹³, Hein Heidbuchel⁴, Ellen Hoffmann¹⁴, Robert Fagard⁴, Silvia G. Priori¹⁵, Cristina Basso¹⁹, Eloisa Arbustini¹⁶, Carina Blomstrom-Lundqvist¹⁷, William J. McKenna¹⁸, and Gaetano Thiene¹⁹
The 2009 IOC Consensus Statement

The International Olympic Committee (IOC) Consensus Statement on periodic health evaluation of elite athletes March 2009

Arne Ljungqvist,1 Peter Jenoure,2 Lars Engebretsen,3,4 Juan Manuel Alonso,5 Roald Bahr,4 Anthony Clough,6,7 Guido De Bondt,8 Jiri Dvorak,9 Robert Maloley,10 Gordon Matheson,11 Willem Meeuwisse,12,13 Erik Meijboom,14 Margo Mountjoy,15 Antonio Pelliccia,16 Martin Schwellnus,17 Dominique Sprumont,18 Patrick Schamasch,19 Jean-Benoît Gauthier,19 Christophe Dubi,19 Howard Stupp,19 Christian Thill19
Thank you for your attention

See also : www.antoniopelliccia.it