Electrocardiogram in the Athlete

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Martín Ibarrola MD, FAHA
Centro Cardiovascular BV
Director of Medical Department of Sports
Rugby and Hockey. Club Regatas de Bella Vista
Argentina
Pre-participation screening can prevent sudden cardiac death in the athletes

- **Medical history:**
  - Personal history.
  - Family history
  - Physical examination

- **ECG changes** that would be considered abnormal in the untrained population may develop in trained athletes as a physiologic and benign consequence of the heart's adaptation to exercise.
Italian program

- Young competitive athletes aged 12 to 35 years are included.
- 2 consecutive screening periods (1982-1992 and 1993-2004) in Italian program. The number of competitive athletes aged 12 to 35 years in the Veneto region from 1982 to 2004 was 423,386 athletes.
Interpretation of ECG in athlete’s

- Recommendations for interpretation of 12-lead electrocardiogram in the athlete. ESC REPORT. European Heart Journal 2010. Corrado D. MD; et al.
- Improving the interpretation of the athlete’s electrocardiogram. EDITORIAL. Corrado D. el al. European Heart Journal 2013
European Society of Cardiology (ESC) classification of ECG abnormalities in athletes

- Sinus bradycardia
- First degree AV block
- Notched QRS in V1 or incomplete RBBB
- Early repolarization
- Isolated QRS voltage criteria for left ventricular hypertrophy

(Group 1) common (up to 80%)

- 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

(Group 2) uncommon (< 5%)
Recommendations for interpretation of 12-lead electrocardiogram in the athlete

Group 1: common and training-related ECG changes (>80%)
- Sinus bradycardia
- First-degree AV block
- Incomplete RBBB
- Early repolarization
- Isolated QRS voltage criteria for left ventricular hypertrophy

Group 2: uncommon and training-unrelated ECG changes (<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
- Ventricular pre-excitation
- Complete LBBB or RBBB
- Long- or short-QT interval
- Brugada-like early repolarization

The ‘Seattle Criteria’: Electrocardiographic interpretation in athletes (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

Abnormal ECG findings in athletes (1)

- 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 ventricular hypedepth and ≥40 ms in duration in lead V1
- Right 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)
- 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


(1) And the Right bundle branch block QRS >120ms and <139 ms?
(1) In Seattle Criteria normal o abnormal findings in athletes

- The author have omitted mention of Complete Right bundle branch block 
  QRS ≥120 ms and < 140 ms.
I send to author a letter about this point about the implication of this and respond by mail

“Dear Dr. Ibarrola,
Thank you for the note. I appreciate your comments regarding RBBB.
I think the pre-test probability that complete RBBB represents disease in most 
asymptomatic athlete populations is very low. Thus, in most settings I don’t think 
RBBB has a high positive predictive value and will not be a good distinguisher of disease.

You bring up an important point that was not addressed in the Seattle summit papers 
-- that RBBB in countries with a high prevalence of Chagas disease should be 
considered abnormal. This will be considered in any future revisions to the criteria.”

Response by Jonathan Drezner, MD

This omitting affected papers compared to ESC recommendation compared with the 
Seattle Criteria. The complete RBBB have present in 1% of athletes (Pelliccia et al. 
EHJ 2007) but is normal o abnormal findings in athletes? In countries with Chagas 
disease, if reasonable? Affected this the support of better false positive in 
comparative paper’s?
Interpretation of the athlete’s electrocardiogram

Group 1
Common/training-related
- Sinus bradycardia
- First degree AV block
- Notched QRS in V1 or incomplete RBBB
- Early repolarization
- Isolated QRS voltage criteria † for LV hypertrophy
- Isolated QRS voltage criteria † for RV hypertrophy

Group 2
Uncommon/training-unrelated
- T-wave inversion
- ST segment depression
- Pathologic Q waves
- Complete RBBB or LBBB
- Non voltage criteria for RV hypertrophy
- Ventricular pre-excitation
- Long or short QT interval
- Brugada-like early repolarization

Major

Minor
- Left axis deviation
- Right axis deviation
- Left atrial enlargement
- Right atrial enlargement

Electrocardiographic Findings in athletes normal variants

GROUP 1
Increased vagal tone

Changes of increased cavity dimensions and wall thickness
Sinus bradycardia ($\geq 30$ bpm). P wave must have a normal axis in the frontal plane (0–90°s)

Male 27 years old. Rugby player. Sinus bradycardia 41 bpm
Sinus arrhythmia

Female 14 years old. Voley. 64 BPM. Sinus arrhythmia
Ectopic atrial rhythm: P waves are present but are a different morphology compared to the sinus P wave, negative in the inferior leads (II, III and aVF)
Junctional escape rhythm or nodal rhythm

Male 15 years old. Rugby player. Asyntomatic. Nodal rhytmin
First-degree AV block: PR interval is prolonged (>200 ms)

Male, Rugby player, asymptomatic with BAV 1er grade 0.24 ms
Second-degree AV block: Mobitz type I (Wenckebach)

Early repolarization: concave ST segment elevation in the precordial leads.

New definitions of Early Repolarization

Types 1, 3 and 5 all have an elevated ST amplitude ≥0.1 mV with or without a notch or slur while Types 2 and 4 have the peak of a notch or onset of a slur ≥0.1 mV but without ST elevation.

Isolated QRS voltage criteria for LVH for Sokolow-Lyon criterion
Incomplete right bundle branch block

Male 17 years. IRBBB
Abnormal electrocardiographic findings in athletes

GROUP 2
Mimics incomplete Right bundle branch block

- Abnormal IRBBB pattern associated with other ECG abnormalities, T wave inversion involving the mid-precordial leads to V1–V3, prolonged S wave upstroke in individuals >14 years of age, low limb-lead voltages, prolonged S wave upstroke and/or premature ventricular beats with a left bundle branch block (LBBB) morphology and Epsilon waves in ARRHYTHMOGENIC RIGHT VENTRICULAR CARDIOMYOPATHY

- Brugada-ECG pattern, which is characterized by a high take-off and downsloping ST segment elevation followed by a negative T wave in ≥2 leads in V1–V3. ‘J wave’ reflects early repolarisation with J point elevation and a high take-off with downsloping ST segment followed by a negative T wave
Criteria for diagnosis of ARVC/D

1. **Family history**
   **Major**
   - Familial disease confirmed at necropsy or surgery.
   **Minor**
   - Family history of premature sudden death (<35 years of age) due to suspected ARVC/D.
   - Family history (clinical diagnosis based on present criteria).

2. **ECG depolarization/conduction abnormalities**
   **Major**
   - Epsilon waves or localized prolongation (>110 ms) of QRS complex in right precordial leads (V1-V3).
   **Minor**
   - Late potentials on signal-averaged ECG.

3. **ECG repolarization abnormalities**
   **Minor**
   - Inverted T waves in right precordial leads (V2 and V3) in people >12 years of age and in absence of right bundle branch block.

4. **Arrhythmias**
   **Minor**
   - Sustained or nonsustained left bundle branch block-type ventricular tachycardia documented on ECG or Holter monitoring or during exercise testing.
   - Frequent ventricular extrasystoles (>1000/24 h on Holter monitoring).

5. **Global or regional dysfunction and structural alterations**
   **Major**
   - Severe dilatation and reduction of RV ejection fraction with no or mild LV involvement.
   - Localized RV aneurysms (akinetic or dyskinetic areas with diastolic bulgings). Severe segmental dilatation of RV.
   **Minor**
   - Mild global RV dilatation or ejection fraction reduction with normal LV.
   - Mild segmental dilatation of RV.
   - Regional RV hypokinesia.

6. **Tissue characteristics of walls**
   **Major**
   - Fibro-fatty replacement of myocardium on endomyocardial biopsy.

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* Detected by echocardiography, angiography, magnetic resonance imaging, or radionuclide scintigraphy. Modified from McKenna et al.
BRUGADA PATTERN

TYPE-1
TYPE-2

- The differential diagnosis of Type-2 Brugada pattern and electrocardiogram of athletes

Chevallier S, et al. New electrocardiographic criteria for discriminating between Brugada types 2 and 3 patterns and incomplete right bundle branch block.

- **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
- **Pathological Q waves.** >3 mm in depth or >40 ms in duration in two or more leads (except 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
- **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. LBBB morphology and an inferior axis (positive in the inferior leads) originate in right ventricular outflow tract. LBBB morphology and superior axis (negative in the inferior leads) originate in the right ventricular free wall or apex and are more suggestive of ARVC
- **Ventricular arrhythmias.** Couplets, triplets and non-sustained ventricular tachycardia
Cadiomyopathyes

- HYPERTROPHIC CARDIOMYOPATHY. 12-lead ECG pattern is abnormal in 75% to 95% of HCM patients
- DILATED CARDIOMYOPATHY. individuals with asymptomatic LV dysfunction, 90% have abnormal ECG findings. 1) LVH in the anterior precordial leads; (2) low limb lead voltage and (3) poor precordial R wave progression
- LV NON-COMPACTION. ECG abnormalities in isolated LVNC are common but nonspecific. most common abnormalities in this series included repolarisation changes (72%), QT prolongation (52%), ST segment depression (51%), TWI (41%), LVH voltage criteria (38%), IVCD (31%) including LBBB (19%) and RBBB (3%), and LAE (26%)
- OTHER ECG FINDINGS POSSIBLY SUGGESTIVE OF A CARDIOMYOPATHY, nonspecific IVCD with QRS duration <140 ms, and isolated (one per tracing) ectopic/premature ventricular contractions (PVCs) have been associated with an underlying cardiomyopathy in non-athletic populations. asymptomatic athletes with an isolated complete (≥120 ms-139 ms) or incomplete (100–119 ms) RBBB, no further diagnostic evaluation is required
T wave inversion. >1 mm in depth in two or more leads V2–V6, II and aVF or I and aVL

Male 14 years old. Rugby. Asymptomatic.
Male 16 years. Rugby.
Male 22 years. Rugby. Asymptomatic.
Complete Right bundle branch block. QRS ≥ 120 ms

Male 28 years. Rugby player. Asymptomatic. QRS axis 179°, QRS 139 ms.
Complete Left bundle branch block. QRS ≥ 120 ms

Male 38 years. Asintomatic. HTA (enalapril 10 mg c/12 hs). IMC 2.12. 2013
Irregular control de BP. New control 2014 and?
Ventricular pre-excitation

Male 14 years. Rugby. Asymptomatic

Female 14 years. Asymptomatic

Male 12 years. Asymptomatic
Premature ventricular contractions $\geq 2$ PVCs per 10 s tracing

Male 16 years. PVC.
Long QT interval

Male 16 years. Hockey. QTC 452 ms.
Normal in male 470 ms
Cadiomyopathies

34 años con miocardiopatía dilatada, onda T invertidas y QTc 513 mseg
Male 14 years. Rugby. QTC 374 ms. Short QR <329 ms
And long time?
The definition of an abnormal ECG using the (A) refined criteria, (B) European Society of Cardiology (ESC) recommendations, and (C) Seattle criteria.

<table>
<thead>
<tr>
<th>ECG Abnormality</th>
<th>ESC Recommendations</th>
<th>Seattle Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left atrial enlargement</td>
<td>Negative portion of the P wave in lead V1 ≥0.1 mV in depth and ≥40 ms in duration</td>
<td>Prolonged P wave duration of &gt;120 ms in lead I or II with negative portion of the P wave ≥1 mm in depth and ≥40 ms in duration in lead</td>
</tr>
<tr>
<td>Right atrial enlargement</td>
<td>P-wave amplitude ≥2.5 mm in lead II, III, or aVF</td>
<td>As ESC</td>
</tr>
<tr>
<td>Left QRS axis deviation</td>
<td>−30° to −90°</td>
<td>As ESC</td>
</tr>
<tr>
<td>Right QRS axis deviation</td>
<td>&gt;115°</td>
<td>&gt;120°</td>
</tr>
<tr>
<td>Right ventricular hypertrophy</td>
<td>Sum of R wave in V1 and S wave in V5 or V6 ≥10.5 mm</td>
<td>Sum of R wave in V1 and S wave in V5 &gt;10.5 mm and right axis deviation &gt;120°</td>
</tr>
<tr>
<td>Complete LBBB</td>
<td>QRS ≥120 ms, predominantly negative QRS complex in lead V1 (QS or rS), and upright monophasic R wave in leads I and V6</td>
<td>As ESC</td>
</tr>
<tr>
<td>Complete RBBB</td>
<td>RSR’ pattern in anterior precordial leads with QRS duration ≥120 ms</td>
<td>Not relevant</td>
</tr>
<tr>
<td>Intraventricular conduction delay</td>
<td>Any QRS duration &gt;120 ms including RBBB and LBBB</td>
<td>Any QRS duration ≥140 ms or complete LBBB</td>
</tr>
<tr>
<td>Pathological Q-wave</td>
<td>&gt;4 mm deep in any lead except III, aVR</td>
<td>&gt;3 mm deep or &gt;40 ms duration in ≥2 leads except III and aVR</td>
</tr>
<tr>
<td>Significant T-wave inversion</td>
<td>≥2 mm in ≥2 adjacent leads (deep) or “minor” in ≥2 leads</td>
<td>&gt;1 mm in depth in ≥2 leads V2–V6, II and aVF, or I and aVL (excludes III, aVR, and V1)</td>
</tr>
<tr>
<td>ST-segment depression</td>
<td>≥0.5 mm deep in ≥2 leads</td>
<td>As ESC</td>
</tr>
<tr>
<td>Ventricular preexcitation</td>
<td>PR interval &lt;120 ms with or without delta wave</td>
<td>PR interval &lt;120 ms with delta wave</td>
</tr>
</tbody>
</table>
Trends in Sudden Cardiovascular Death in Young Competitive Athletes After Implementation of a Preparticipation Screening Program
Recommendations for interpretation of 12-lead electrocardiogram in the athlete

![Flowchart of recommendations](image-url)
Bethesda Conference #36 and the European Society of Cardiology Consensus Recommendations Revisited

A Comparison of U.S. and European Criteria for Eligibility and Disqualification of Competitive Athletes With Cardiovascular Abnormalities


Mandatory reporting systems for SDs in young people (including athletes) do not exist in the countries, analyses of event frequency, are usually highly dependent on accounts in the public record, from the Internet, or from personal communications for the identification of events that provide important epidemiological and clinical information.
Thank you
Obrigado
Muchas gracias