

**TABLE 1 International Consensus Standards for Electrocardiographic Interpretation in Athletes: Definitions of ECG Criteria****Abnormal ECG findings in athletes**

These ECG findings are unrelated to regular training or expected physiologic adaptation to exercise, may suggest the presence of pathologic cardiovascular disease, and require further diagnostic investigation.

ECG abnormality	Definition
T wave inversion	$\geq 1$ mm in depth in two or more contiguous leads; excludes leads aVR, III, and V <sub>1</sub>
• Anterior	• V <sub>2</sub> -V <sub>4</sub> - excludes: black athletes with J-point elevation and convex ST-segment elevation followed by TWI in V <sub>2</sub> -V <sub>4</sub> ; athletes age <16 with TWI in V <sub>1</sub> -V <sub>3</sub> ; and biphasic T waves in only V <sub>3</sub>
• Lateral	• I and aVL, V <sub>5</sub> and/or V <sub>6</sub> (only one lead of TWI required in V <sub>5</sub> or V <sub>6</sub> )
• Inferolateral	• II and aVF, V <sub>5</sub> -V <sub>6</sub> , I and aVL
• Inferior	• II and aVF
ST-segment depression	$\geq 0.5$ mm in depth in two or more contiguous leads
Pathologic Q waves	Q/R ratio $\geq 0.25$ or $\geq 40$ ms in duration in two or more leads (excluding III and aVR)
Complete left bundle branch block	QRS $\geq 120$ ms, predominantly negative QRS complex in lead V <sub>1</sub> (QS or rS), and upright notched or slurred R wave in leads I and V <sub>6</sub>
Profound nonspecific intra-ventricular conduction delay	Any QRS duration $\geq 140$ ms
Epsilon wave	Distinct low amplitude signal (small positive deflection or notch) between the end of the QRS complex and onset of the T-wave in leads V <sub>1</sub> -V <sub>3</sub>
Ventricular pre-excitation	PR interval <120 ms with a delta wave (slurred upstroke in the QRS complex) and wide QRS ( $\geq 120$ ms)
Prolonged QT interval*	QTc $\geq 470$ ms (male) QTc $\geq 480$ ms (female) QTc $\geq 500$ ms (marked QT prolongation)
Brugada Type 1 pattern	Coved pattern: initial ST-segment elevation $\geq 2$ mm (high take-off) with downsloping ST-segment elevation followed by a negative symmetric T-wave in $\geq 1$ leads in V <sub>1</sub> -V <sub>3</sub>
Profound sinus bradycardia	<30 beats/min or sinus pauses $\geq 3$ s
Profound 1° AV block	$\geq 400$ ms
Mobitz Type II 2° AV block	Intermittently non-conducted P waves with a fixed PR interval
3° AV block	Complete heart block
Atrial tachyarrhythmias	Supraventricular tachycardia, atrial fibrillation, atrial flutter
PVC	$\geq 2$ PVCs per 10 s tracing
Ventricular arrhythmias	Couplets, triplets, and non-sustained ventricular tachycardia

**Borderline ECG findings in athletes**

These ECG findings in isolation likely do not represent pathologic cardiovascular disease in athletes, but the presence of two or more borderline findings may warrant additional investigation until further data become available.

ECG abnormality	Definition
Left axis deviation	$-30^\circ$ to $-90^\circ$
Left atrial enlargement	Prolonged P wave duration of >120 ms in leads I or II with negative portion of the P-wave $\geq 1$ mm in depth and $\geq 40$ ms in duration in lead V <sub>1</sub>
Right axis deviation	$>120^\circ$
Right atrial enlargement	P-wave $\geq 2.5$ mm in II, III, or aVF
Complete right bundle branch block	rSR' pattern in lead V <sub>1</sub> and a S wave wider than R wave in lead V <sub>6</sub> with QRS duration $\geq 120$ ms

**Normal ECG findings in athletes**

These training-related ECG alterations are physiologic adaptations to regular exercise, considered normal variants in athletes, and do not require further evaluation in asymptomatic athletes with no significant family history.

Normal ECG finding	Definition
Increased QRS voltage	Isolated QRS voltage criteria for left (SV <sub>1</sub> + RV <sub>5</sub> or RV <sub>6</sub> >3.5 mV) or right ventricular hypertrophy (RV <sub>1</sub> + SV <sub>5</sub> or SV <sub>6</sub> >1.1 mV)
Incomplete RBBB	rSR' pattern in lead V <sub>1</sub> and a qRS pattern in lead V <sub>6</sub> with QRS duration <120 ms
Early repolarization	J-point elevation, ST-segment elevation, J waves, or terminal QRS slurring in the inferior and/or lateral leads
Black athlete repolarization variant	J-point elevation and convex ('domed') ST-segment elevation followed by T-wave inversion in leads V <sub>1</sub> -V <sub>4</sub> in black athletes
Juvenile T-wave pattern	T-wave inversion V <sub>1</sub> -V <sub>3</sub> in athletes age <16 yrs
Sinus bradycardia	$\geq 30$ beats/min
Sinus arrhythmia	Heart rate variation with respiration: rate increases during inspiration and decreases during expiration
Ectopic atrial rhythm	P waves are a different morphology compared with the sinus P-wave, such as negative P waves in the inferior leads ('low atrial rhythm')
Junctional escape rhythm	QRS rate is faster than the resting P-wave or sinus rate and typically <100 beats/min with narrow QRS complex unless the baseline QRS is conducted with aberrancy
1° AV block	PR interval 200-400 ms
Mobitz Type I (Wenckebach) 2° AV block	PR interval progressively lengthens until there is a non-conducted P-wave with no QRS complex; the first PR interval after the dropped beat is shorter than the last conducted PR interval

\*The QT interval corrected for heart rate is ideally measured using Bazett's formula with heart rates between 60 and 90 beats/min; preferably performed manually in lead II or V<sub>5</sub> using the teach-the-tangent method<sup>1</sup> to avoid inclusion of a U-wave (please see text for more details). Consider repeating the ECG after mild aerobic activity for a heart rate <50 beats/min, or repeating the ECG after a longer resting period for a heart rate >100 beats/min, if the QTc value is borderline or abnormal.

AV = atrioventricular block; ECG = electrocardiogram; PVC = premature ventricular contraction; RBBB = right bundle branch block.