Module 1. Electrocardiogram in athletes

BARÇA INNOVATION HUB
Universitas

Unit 1.1 Physiological adaptation to sport

Regular and sustained physical exercise (a minimum of 4 hours per week) leads to typical electrocardiographic manifestations that reflect benign structural and electrical remodeling of the heart, resulting in cardiac cavities enlargements and increased vagal tone (Sharma et al., 2017). These findings are considered normal, typical of a physiological adaptation to sport and, therefore, do not require additional diagnostic studies. Thus, it is essential to know the distinctive features of the normal electrocardiogram (ECG) in the athlete in order to detect underlying cardiac diseases that increase the risk of sudden death. This is why this diagnostic tool is a fundamental element in the pre-participation screening of athletes.

In this section, we will detail the characteristics of the normal ECG in athletes along with the borderline findings. Finally, in the last section, we will analyze those findings considered pathological and that, therefore, require additional diagnostic studies to rule out the presence of a heart disease.

1.1.1 Characteristics of a normal ECG in athletes

1 **Increased QRS complex voltage**

An increase in QRS complex voltage, meeting the criteria for left ventricular hypertrophy (LVH) according to the Sokolow-Lyon index (S in V1 + R in V5 or V6 >35 mm), if present in isolation (i.e., without other associated electrocardiographic abnormalities such as negative T waves in lateral and inferior leads, pathological Q waves or ST-segment depression), is considered a normal finding in the athlete's ECG and does not indicate the presence of underlying pathology (Ryan et al., 1995) (Figure 1).

Similarly, the isolated presence of signs of right ventricular hypertrophy based on the increased voltage criterion (Sokolow-Lyon index: R V1 + S V5 or V6 >11 mm) is part of the normal ECG spectrum in athletes and does not require additional diagnostic testing (Zaidi et al., 2013).

Figure 1. Electrocardiogram

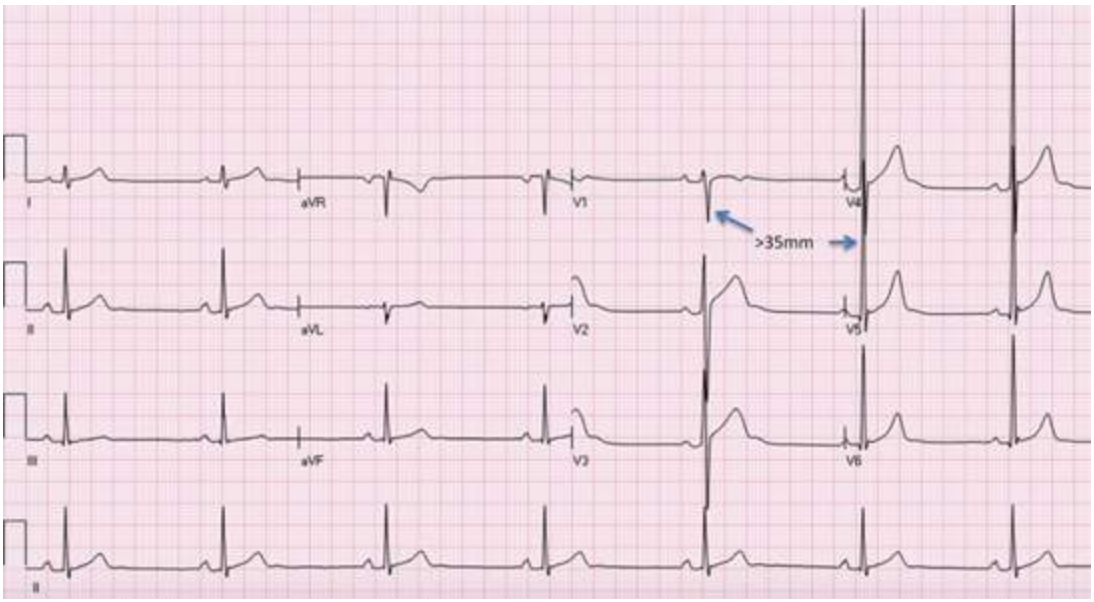

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Figure 1. A 22-year-old asymptomatic triathlete with a training load of 7 hours per week. The ECG shows a Sokolow-Lyon index greater than 35 mm, thus meeting the criteria for left ventricular hypertrophy; however, in this context and in isolation (i.e. without signs of ventricular overload), it is considered a normal electrocardiographic finding in the athlete, and, therefore, does not require any additional complementary testing.

2 Incomplete right bundle branch block

Incomplete right bundle branch block is defined as an rSR' pattern in V1 + qRS in V6 with a QRS complex duration <120 ms. Its estimated

frequency in the general population is 5-10%; it is more frequent in young athletes (around 35-50%). The increase in right ventricle (RV) size in athletes, as a consequence of physiological remodeling, is considered to lead to a slight delay in electrical conduction in this cavity. This is why the isolated presence of incomplete right bundle branch block in athletes does not imply the existence of an underlying structural heart disease (Sharma et al., 2017).

Figure 2. A 29-year-old amateur cyclist with a training load of 8 hours per week

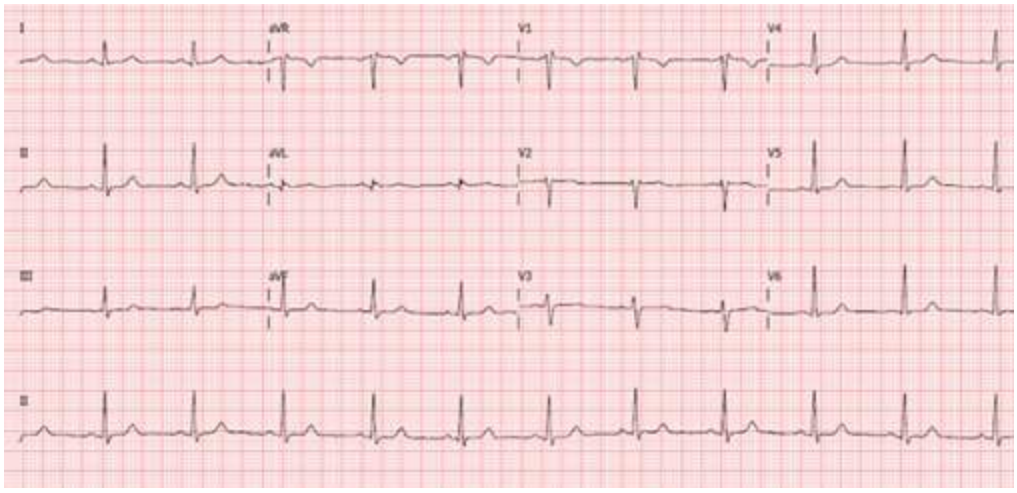

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Figure 2. A 29-year-old amateur cyclist with a training load of 8 hours per week. The ECG routinely performed shows an incomplete right bundle branch block with rSR' pattern in V1 + qRs in V6 + QRS duration <120 ms. And, since it is not associated with other findings that

suggest an underlying heart disease, it does not require any complementary study.

Early repolarization pattern

Early repolarization is defined as an elevation of the J point (junction between the QRS complex and the ST segment) →0.1 mV along with prominent T waves (MacFarlane et al., 2015). It is a very frequent finding (>50%) in well-trained athletes, especially in males and Black athletes. It is considered a benign entity (Tikkanen et al., 2011) (Figure 3).

Occasionally, it is also possible to observe the presence of slurring at the end of the QRS complex (J wave) along with the above features (MacFarlane et al., 2015) (Figure 4).

Based on current evidence, both early repolarization patterns, when present in isolation and without clinical markers of pathologies, should be considered benign variants in athletes (MyEKG, n. d.).

Figure 3. Early repolarization pattern with J-point elevation

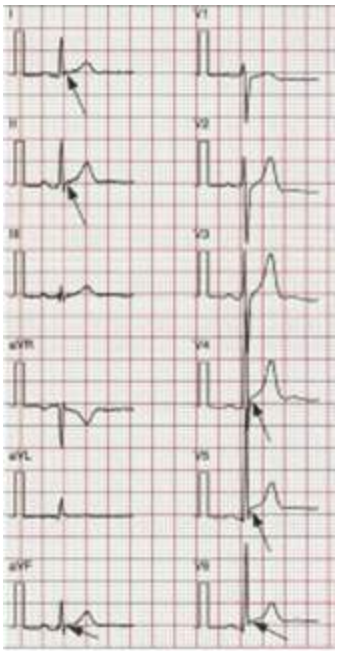

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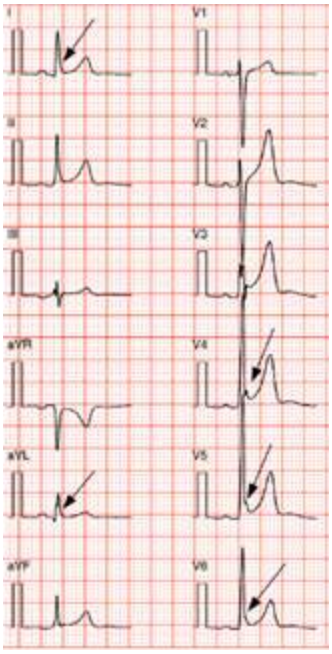
Figure 4. Early repolarization pattern with J-point elevation and presence of J wave (arrows)



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3 Physiological arrhythmias in athletes

As a consequence of sports-induced enhanced vagal tone, it is very common for the athlete's heart rate (HR) at rest to be less than 50 bpm, a phenomenon we call sinus bradycardia (estimated frequency of up to 80% in well-trained athletes) (Sharma et al., 1999). Between 30 and 50 bpm, sinus bradycardia is considered to be a more adaptive feature of the athlete's ECG (Figure 5). Lower heart rates can be found at rest or during nocturnal rest in endurance athletes with high load volumes; in these cases, it is necessary to confirm that, in response to the exercise stimulus, heart rate increases appropriately. Another frequent finding in athletes, especially at early ages, is sinus arrhythmia (respiratory arrhythmia) (Sharma et al., 1999), which is the physiological variation of heart rate with respiration.

Other frequent findings that also reflect a predominance of the vagal nervous system induced by sports practice are:

- Atrial ectopic rhythm: It is characterized by the presence of P waves of different morphology with respect to sinus waves, usually with negative P waves in inferior leads (Figure 5). Occasionally, P waves of two morphologies may be observed,

which is called wandering pacemaker. Both rhythms are physiological and are present in 8-10% of athletes (Northcote et al., 1989).

- Junctional escape rhythm (nodal rhythm): It occurs when the QRS complexes frequency is higher than the P waves frequency, usually <100 bpm, the R-R intervals are regular and the QRS complexes, in the absence of intraventricular conduction disorders, are narrow (Figure 5) (Northcote et al., 1989).

In case there are no symptoms such as dyspnea, asthenia, head instability or syncope, these rhythm variations are considered to reflect the predominance of the vagal nervous system as a consequence of an adaptive response to exercise. With the exercise stimulus, these rhythms should give way to sinus rhythm and tachycardia should be observed according to the intensity of the exercise practiced.

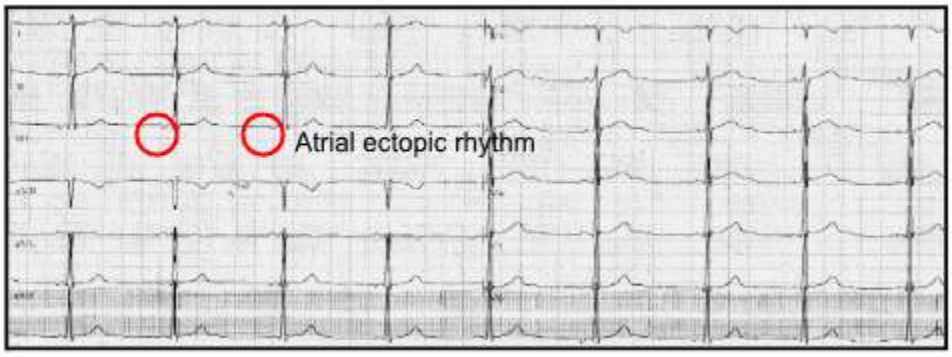
4 Atrioventricular conduction delays

Similar to the previous section, the enhanced vagal tone in highly trained athletes can lead to the following types of atrioventricular conduction delays (Figure 7):

-First-degree atrioventricular block: In this case, the PR interval is prolonged (>200 ms); it must always be less than 400 ms to be considered physiological. It occurs in up to 7.5% of the athletic population (Sharma et al., 2017) (Figure 8).

-Type I second-degree atrioventricular block (Wenckebach phenomenon): It occurs when the PR interval progressively lengthens until a P wave stops conducting. Typically, RR intervals are irregular (Meytes et al., 1975) (Figure 7).

Figure 5.



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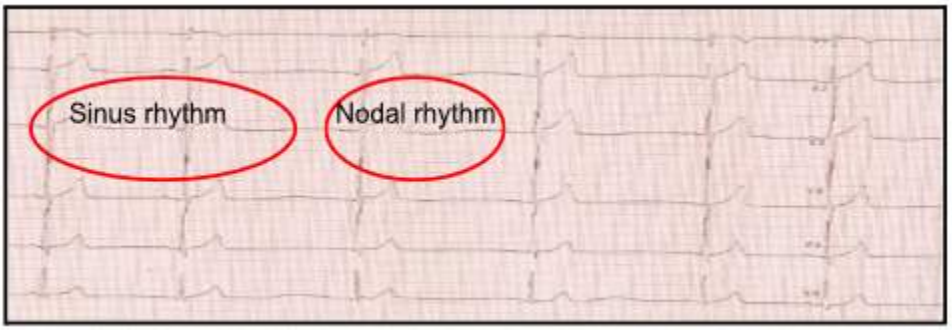

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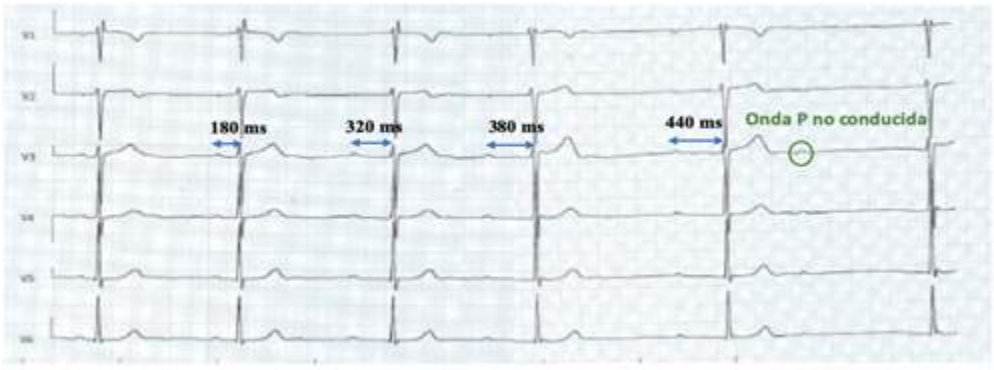
Figures 5 and 6. Both ECGs correspond to a 27-year-old male endurance athlete with high training volumes (10 hours per week since the age of 12). The first (5) shows a low atrial rhythm, and the second (6), a nodal rhythm.

Figure 7.



Non-conducted P wave

Figure 8.

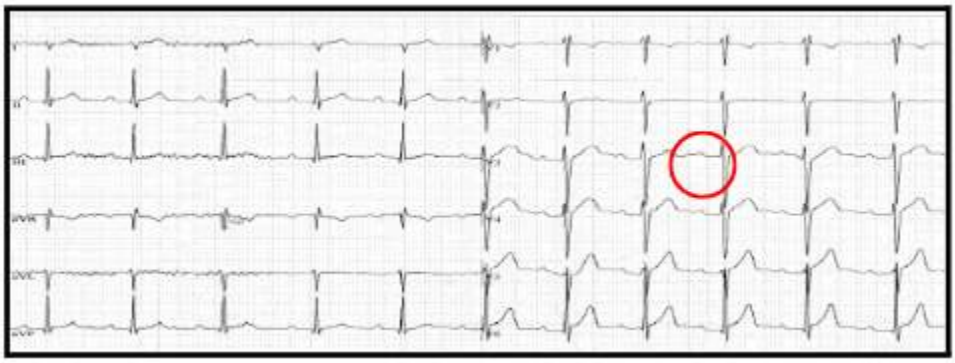


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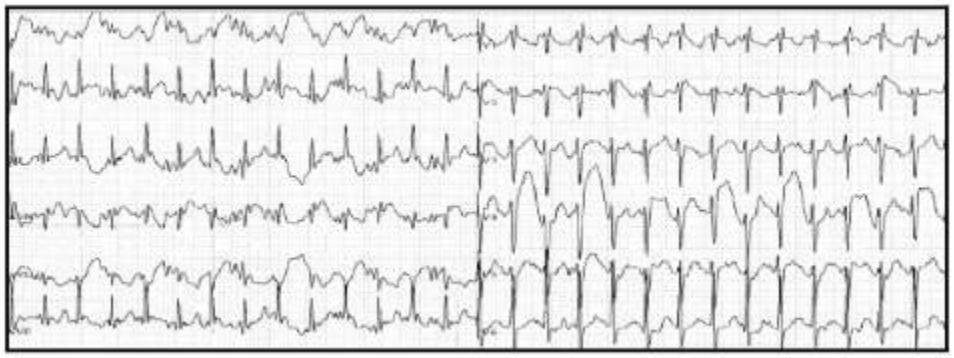
Figure 9.



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Figures 7, 8 and 9. ECG of a 19-year-old elite soccer player: (6a) ECG at rest in the supine position, Mobitz I second-degree atrioventricular block where the PR interval progressively lengthens until a P wave stops conducting; (6b) first-degree atrioventricular block after

adopting the standing position; (6c) with exercise stimulus, normal atrioventricular conduction is restored.

5 Special considerations by population group

- **5.1. Electrocardiogram in Black athletes**

Ethnicity is an important factor, decisive for the cardiac adaptation to exercise. In this regard, Black athletes very frequently present a variant in repolarization, consisting of a J-point elevation and a convex ST-segment elevation in anterior leads (V1-V4), followed by a T-wave inversion (Sheikh et al., 2014) (Figure 10). It is considered a benign variant and, consequently, does not warrant any additional diagnostic testing in the absence of other clinical or electrocardiographic features of cardiomyopathy (Sharma et al., 2017).

Figure 10.

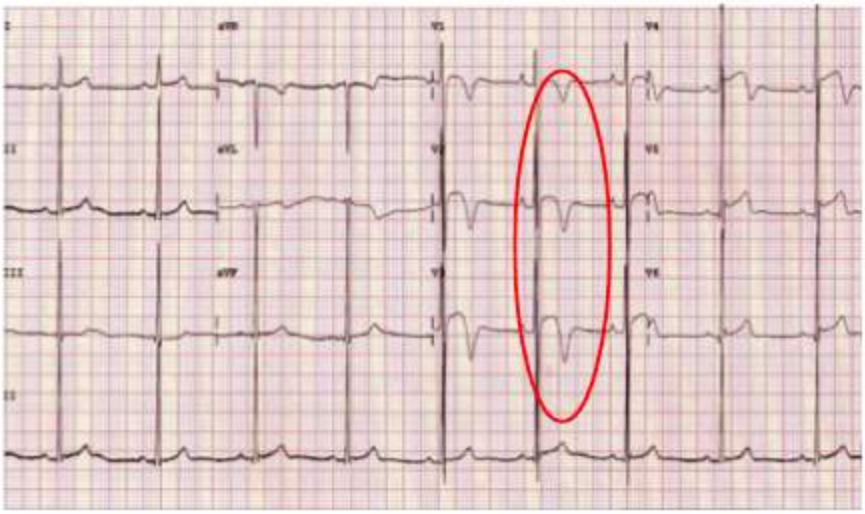

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Figure 10. A 32-year-old Black male athlete, marathon runner, asymptomatic; he has no underlying heart disease, and he has a repolarization pattern that is characteristic of his ethnicity. J-point elevation and convex ST-segment elevation can be observed in V1-V4, followed by T-wave inversion.

- **5.2. Electrocardiogram in female athletes**

Gender is also a factor that determines different cardiac remodeling, and thus may affect repolarization. Female athletes may present negative T waves in leads V1-V2 in up to 4.3% of cases. This is considered a benign finding (Malhorta et al., 2016).

- **5.3. Juvenile T-wave pattern in young athletes (12 to 16 years old)**

"The term 'juvenile T-wave pattern' is used to indicate a T-wave inversion or a bi-phasic T wave beyond lead V2 in adolescents who have not reached physical maturity" (MyEKG, n. d., https://bit.ly/3Ma8tin). This T-wave inversion in the anterior precordial leads (V1-V3) (Figure 11) is considered a normal age-associated pattern in this subgroup of athletes (under 16 years old). This is why, in the absence of symptoms, signs or family history of heart disease, it should not warrant any further study (Sharma et al., 2017).

Figure 11.

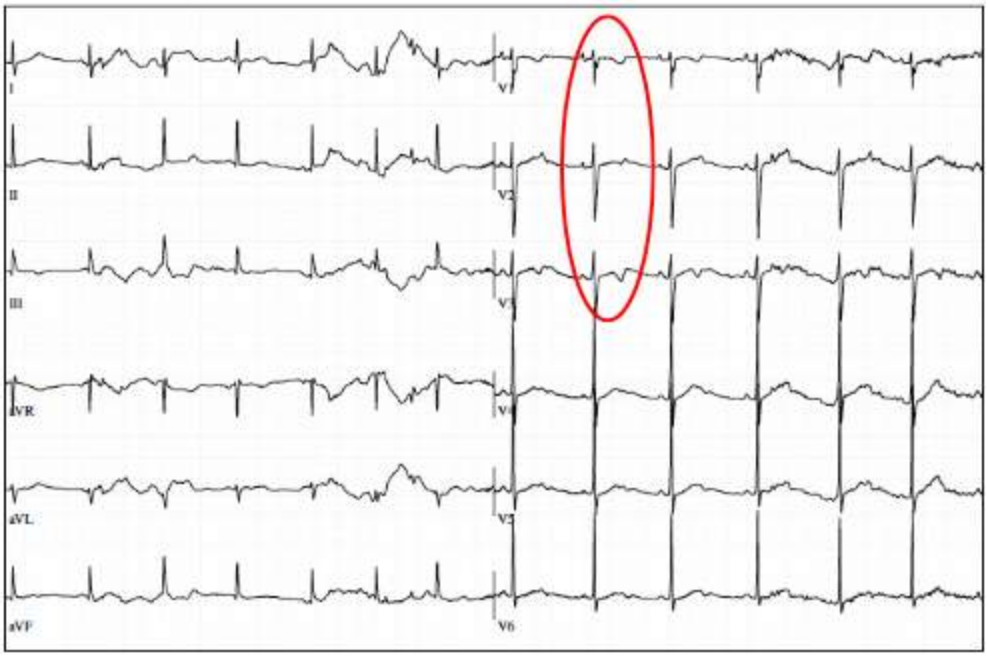

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Figure 11. ECG of an asymptomatic 11-year-old girl volleyball player, where the negative T-wave pattern of V1-V3, characteristic of athletes under 16 years old, can be observed; in the absence of other signs of heart disease, it does not require any additional testing.

1.1.2 Borderline changes in the athlete's ECG

Until recently, the electrocardiographic findings below were considered pathological. However, recent evidence suggests that they are probably a variant of normal, as a consequence of physiological (electrical and structural) adaptation to prolonged training (Sharma et al., 2017):

Left axis deviation (QRS axis between -30° and -90°) and right axis deviation (QRS axis >120º) (Papadakis et al., 2009).

1. Left atrial enlargement (P wave duration >120 ms in leads I or II with the negative portion of the P wave →1 mm in depth and →40 ms duration in V1) (Gati et al., 2013).
2. Right atrial enlargement (P wave →2.5 mm in leads II, III or aVF) (Gati et al., 2013).

Several studies have observed that the criterion of QRS complex axis deviation and atrial enlargement in athletes does not correlate with

the presence of structural heart disease (MyEKG, n. d.). Athletes with an electrocardiographic pattern of left axis deviation or left atrial enlargement have larger sizes of both cavities compared to those athletes with a normal ECG or with findings considered to be typical of the athlete's heart, thus reflecting the structural remodeling of the athlete's heart. On the other hand, no significant differences have been observed in the dimensions of the right cavities in those athletes who present electrocardiographic criteria of right axis deviation and right atrial enlargement. This suggests that, if presented in isolation or with other findings considered as physiological, it is probably a variant of normality (Gati et al., 2013).

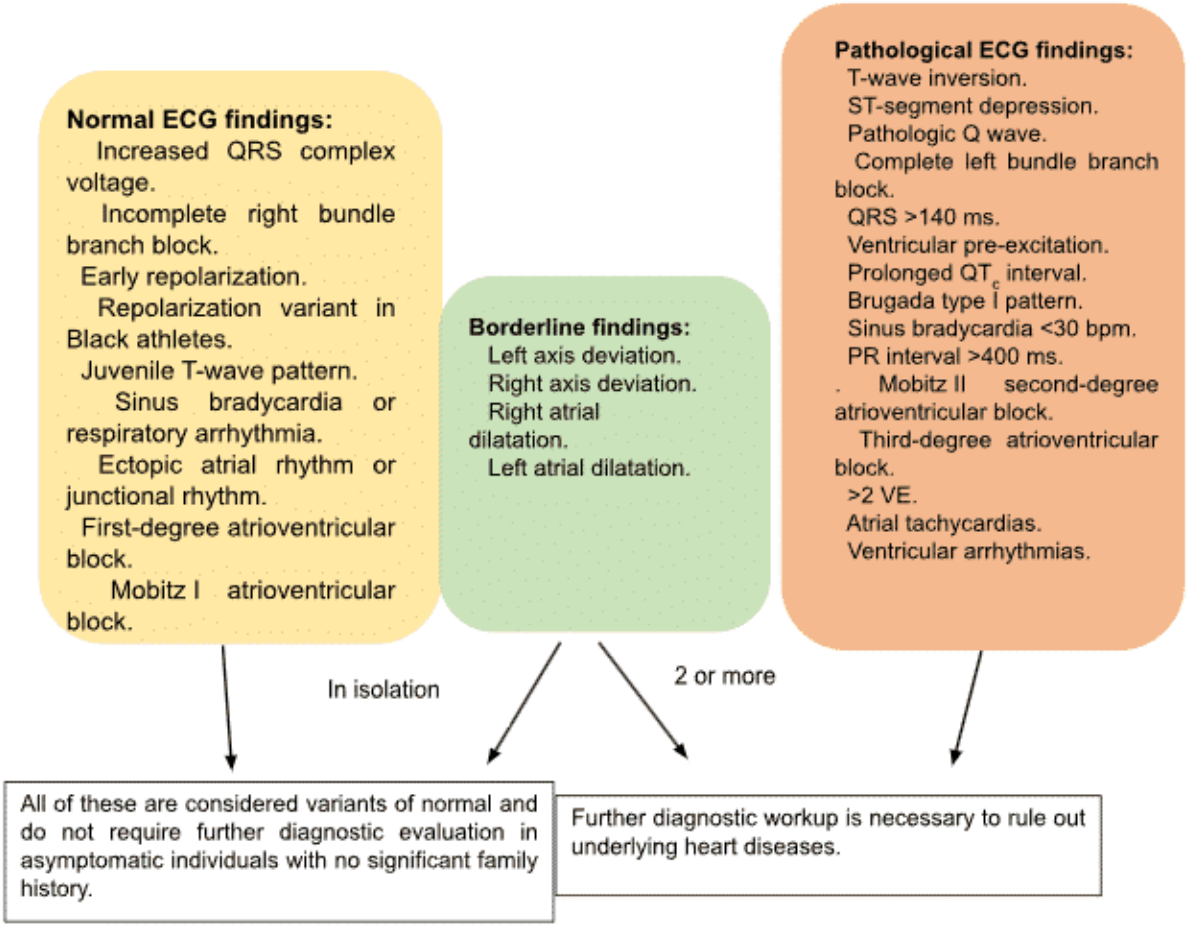
Complete right bundle branch block (RBBB)

Although incomplete right bundle branch block is common in healthy athletes, the significance of RBBB is uncertain. In the previous 2010 guidelines, this finding was considered to be pathological (Corrado et al., 2010). However, it was later confirmed that the presence of an RBBB was associated with a more marked remodeling of the right ventricle reflected in the increased size of this cavity and in a slightly reduced right ventricular function, but in the absence of structural heart disease (Serratosa-Fernández et al., 2017). This is why, along with the incomplete right bundle branch block, RBBB probably represents the RV structural remodeling typical of endurance athletes, characterized by this cavity dilatation with the resulting

prolongation of the QRS interval duration (Serratosa-Fernández et al., 2017).

In conclusion, in asymptomatic athletes with no family history of sudden death or cardiovascular disease, the isolated presence of any of these borderline changes or their existence in conjunction with another electrocardiographic variant of normality (considered physiological) does not warrant additional studies. However, if two or more borderline changes coexist, it will be considered a pathological finding, and, therefore, it should be followed up with the necessary tests to complete the relevant diagnosis (Sharma et al., 2017) (Figure 12).

Figure 12. ECG findings

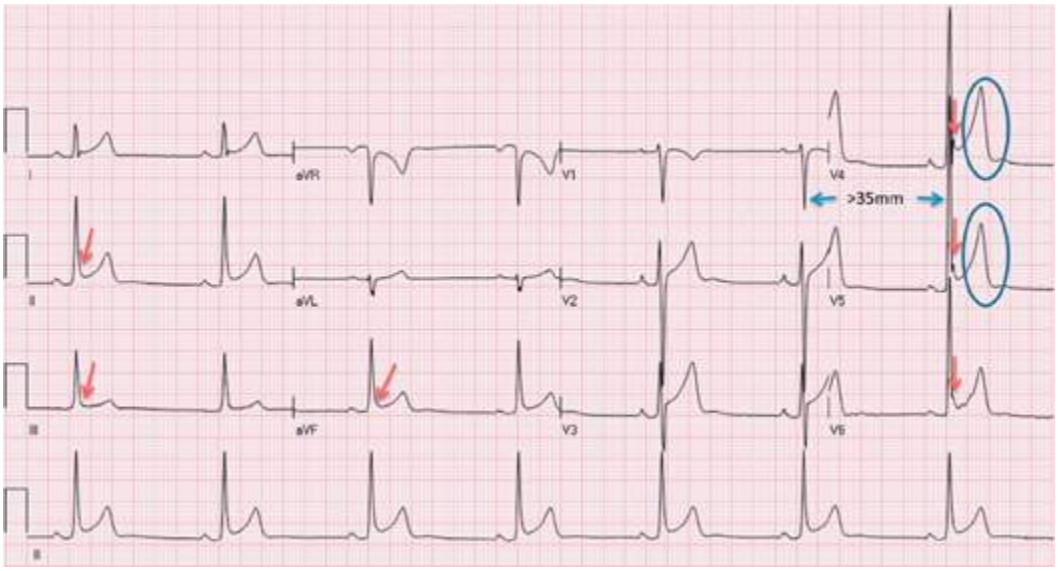


Source: own source based on Sharma *et al.*, 2017.

Electrocardiographic findings specific to the athlete reflect physiological changes resulting from an enhanced vagal tone and exercise-induced structural remodeling (Figure 13). The correct athlete's ECG assessment should be carried out considering: the family and personal history of heart disease or other non-cardiovascular pathologies; the subject's inherent characteristics, such as age, race, sex and sports history, as well as the sport

discipline; current training volume; and years of accumulated training (Figure 14).

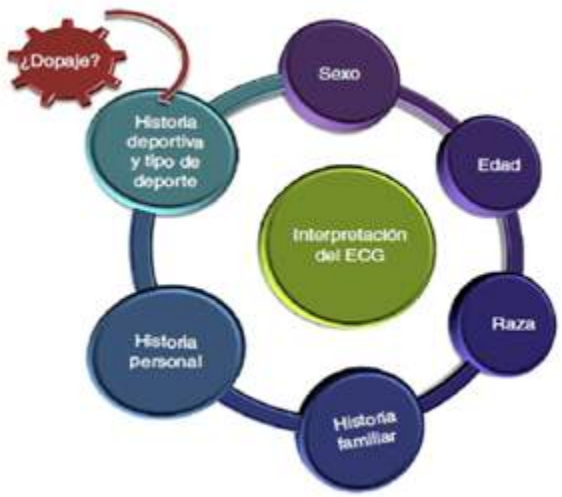
Figure 13.



Source: own source based on Sharma et al., 2017.

Figure 13. ECG of a 29-year-old soccer player showing sinus bradycardia at 44 bpm, early repolarization pattern in inferior and lateral leads (arrows), left ventricular hypertrophy criteria (Sokolow index >35 mm) and peaked T waves (circles). All of them are considered normal in well-trained endurance athletes and do not require additional complementary studies. However, these findings should surprise us if they are observed in an amateur athlete with a predominance of strength training and a lower training volume.

Figure 14. ECG interpretation



Source: own source based on Serratosa-Fernández et al., 2017.

¿Dopaje?	Doping?
Historia deportiva y tipo de deporte	Sports history and type of sport
Historia personal	Personal history
Historia familiar	Family history
Interpretación del ECG	ECG interpretation

Sexo	Sex
Edad	Age
Raza	Race

Pathological findings in the athlete's ECG

The following electrocardiographic findings are not considered secondary to cardiac adaptation to prolonged training; therefore, they are pathological. Their detection always requires completion of the etiological study to rule out an underlying heart disease, and athletes should suspend physical activity until the diagnostic test is completed (Sharma et al., 2017).

- **Pathological T-wave inversion**

The presence of a negative T wave → 1 mm in depth in 2 or more contiguous leads (except in leads aVR, III and V1) is considered pathological. The finding of negative T waves in inferior and/or lateral leads is typical of hypertrophic cardiomyopathy (HCM) (Bent et al., 2015) (Figure 15), whereas their presence in right precordial leads (V1 to V3) or beyond V3, in the absence of a complete right bundle branch block, is common in right ventricle arrhythmogenic cardiomyopathy (AC) (Nasir et al., 2004) (Figure 16).

The diagnostic study will begin with a transthoracic echocardiogram. If this is inconclusive or shows a high suspicion of an underlying heart disease, a cardiac magnetic resonance imaging (MRI) with gadolinium should be performed. Additionally, in the presence of lateral or inferolateral negative T waves, it is recommended to complete the study by means of a stress testing and a 24-hour Holter, especially in those athletes who are in the “gray zone” of ventricular hypertrophy.

There are insufficient data regarding the clinical significance of flat or bi-phasic T waves in athletes, but further diagnostic evaluation is recommended when the bi-phasic T wave negative portion is → 1 mm in depth in 2 or more contiguous leads.

We should remember that the typical repolarization pattern in Black athletes and the juvenile T-wave pattern in individuals under 16 years of age are excluded from this section, since both are considered physiological.

Figure 15.

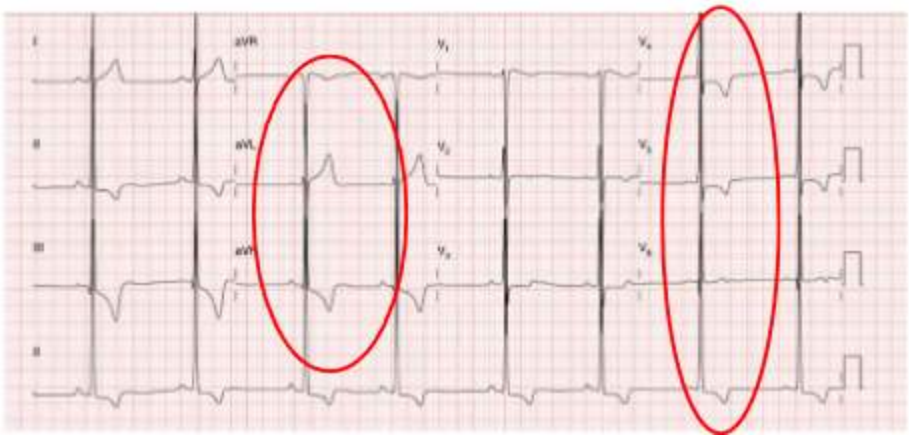


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Figure 15. ECG of a 25-year-old male athlete, water polo player, asymptomatic, showing signs of left ventricular hypertrophy with pathological T waves typical of hypertrophic cardiomyopathy.

Figure 16.

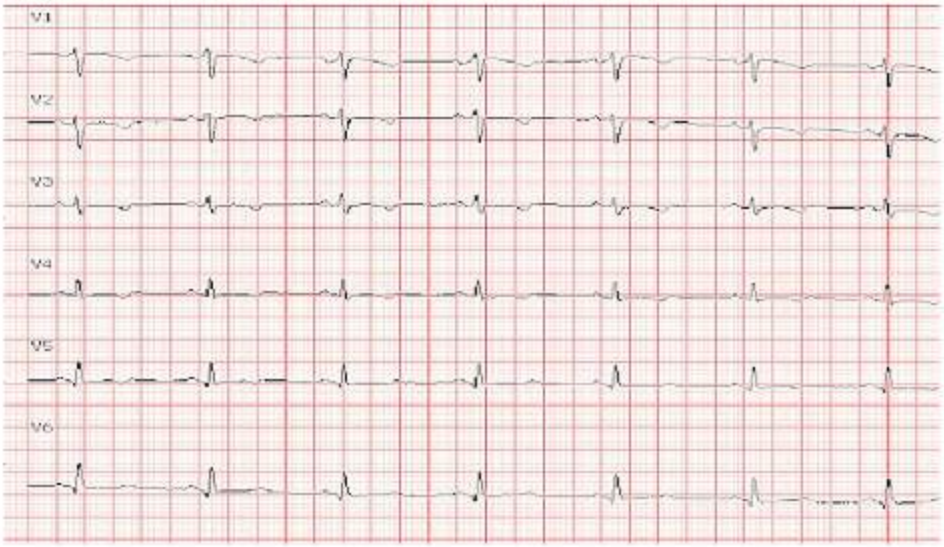

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Figure 16. ECG work screening of a 25-year-old female amateur endurance athlete, asymptomatic, with negative T waves in V1-V4, and low QRS voltage in precordial leads. The athlete has an AC.

- **ST-segment depression**

ST-segment depression >0.05 mV (0.5 mm) in two or more contiguous leads should always be considered pathological, as it does not indicate a cardiac adaptation to exercise (Sharma et al., 2017). This finding may be associated with the presence of HCM, dilated cardiomyopathy (DCM), non-compaction cardiomyopathy, AC or myocarditis (Bent et al., 2015). In these cases, the evaluation of the athlete should be completed with a transthoracic echocardiogram and, depending on the findings or according to clinical suspicion, a cardiac MRI.

- **Pathological Q waves**

A Q wave is considered pathological when the Q/R ratio is →0.25 or →40 ms in duration in two or more contiguous leads, except III and AVR (Sharma et al., 2017). Repeating ECG should be considered when pathological Q waves are observed only in V1 and V2, in case of possible electrode misplacement.

Traditionally, Q waves of >3 mm in depth or >40 ms duration in two or more contiguous leads had been defined as pathological, but this criterion entails a significant percentage of false positives, especially in adolescent athletes with physiological left ventricular hypertrophy and inferior or lateral Q waves (Drezner et al., 2013).

The presence of pathological Q waves may indicate the existence of HCM, AC, infiltrative diseases, accessory pathways and ischemic heart disease. Therefore, in these cases, diagnostic evaluation should continue with a transthoracic echocardiogram. If the latter is normal and there is no high clinical suspicion of the existence of an underlying heart disease, it is not necessary to continue the study. Otherwise, it will be completed by performing a cardiac MRI. In athletes over 30 years of age with clinical suspicion of previous ischemic heart disease or with cardiovascular risk factors, it is also recommended to perform an ischemia screening test (dobutamine stress echocardiogram or stress cardiac MRI) (Sharma et al., 2017).

- **Complete left bundle branch block**

Complete left bundle branch block is a rare finding in athletes (<1/1000 individuals), so its detection should always be considered pathological and it requires transthoracic echocardiogram and cardiac MRI to rule out possible diseases. The pathological entities that can be associated with complete left bundle branch block are: DCM, HCM, non-compaction cardiomyopathy, sarcoidosis or myocarditis.

- **Profound nonspecific intraventricular conduction delay**

The clinical significance of this electrocardiographic finding is uncertain. However, it is likely that the physiological mechanism of the nonspecific intraventricular conduction delay with a QRS of normal morphology is based on the combination of a neurally mediated slowing in the electrical conduction of the fibers together with an increase in left ventricular myocardial mass (Xiao et al., 1994). It will be considered as pathological when this delay is →140 ms; in that case, the study should be continued with a transthoracic echocardiogram (Sharma et al., 2017).

- **Ventricular pre-excitation**

Ventricular pre-excitation occurs when an accessory pathway conducts the electrical impulse from the atrium to the ventricle without passing through the atrioventricular node, thereby shortening the PR interval and the duration of the QRS complex. This is evident on the ECG as the Wolf-Parkinson-White (WPW) pattern, which is defined as a PR interval <120 ms together with the presence of a delta wave (a small slurring in front of the QRS complex) and a QRS duration >120 ms (Figure 17).

The WPW pattern is observed in 1 in 250 athletes (Cohen et al., 2012) and is always pathological, as it can predispose to sudden death by rapidly leading to atrial fibrillation deriving in ventricular fibrillation.

Even in asymptomatic subjects, the presence of a WPW pattern makes it necessary to perform complementary tests in order to stratify the risk associated with this accessory pathway and in order to rule out the presence of underlying structural heart disease. Transthoracic echocardiogram will be performed to rule out Ebstein's disease or other cardiomyopathies that have been associated with the WPW pattern. The risk of sudden death inherent to the accessory pathway will depend on the speed at which such pathway can conduct (i.e., depending on its refractory period). Peak stress testing and Holter ECG recording (including a training session) will help to assess up to what heart rate this pathway conducts. If the pathway disappears during tachycardia at moderate heart rates, it is considered low risk. Likewise, the fact that the WPW pattern is intermittent, i.e., it sometimes appears and sometimes does not on the resting ECG, suggests low-risk characteristics (Cohen et al., 2012). In contrast, an accessory pathway that is permanent and can conduct up to high heart rates poses at greater risk of degenerating into ventricular fibrillation and is therefore considered high risk. Electrophysiological study is indicated when the results of conventional ergometry and/or Holter ECG recording suggest that the pathway may be of higher to lower risk. Such evaluation will allow us to know directly the characteristics of the accessory pathway, stratify the risk and make a therapeutic decision (Klein, G. J. and Gulamhusein, 1983).

Figure 17.

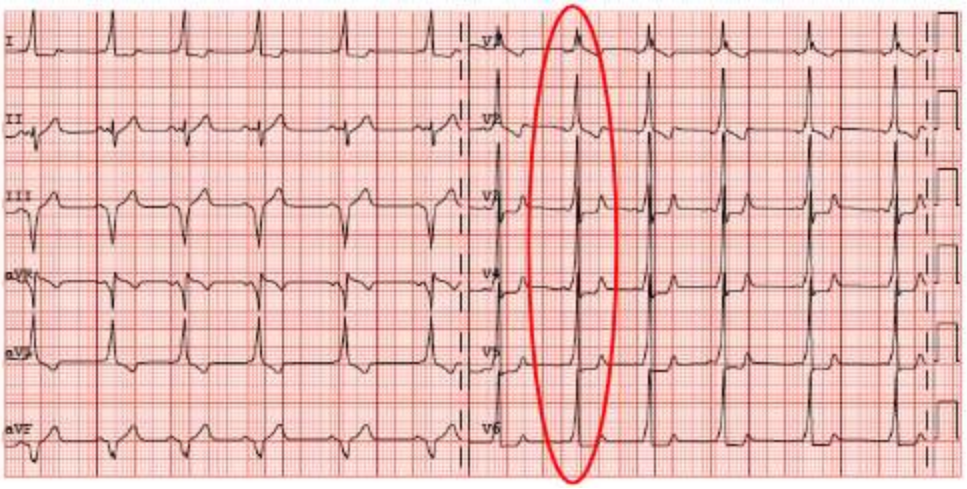

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Figure 17. Swimmer, aged 21, with high training load (>7 hours per week) and occasional episodes of palpitations. The ECG shows the WPW pattern with a PR interval <120 ms with a delta wave and a QRS duration >120 ms. The transthoracic echocardiogram was normal, and simple ergometry was performed, where the pre-excitation did not disappear, so a high-risk accessory pathway was considered, and the athlete underwent ablation.

The finding of a short PR in isolation, that is, a PR interval <120 ms not associated with pre-excitation, does not prompt additional studies, as it is considered a frequent finding within the athletic population (4.9%), especially in young people (9% in those under 14 years of age versus 3.2% between 17 and 35 years of age). It is more frequent in women (6.2% vs. 4.2%). Possible explanations for this physiological finding are the presence of a higher sympathetic tone or a

hyperconducting atrioventricular node (Parry-Williams et al., 2019) (Figure 18).

Figure 18.

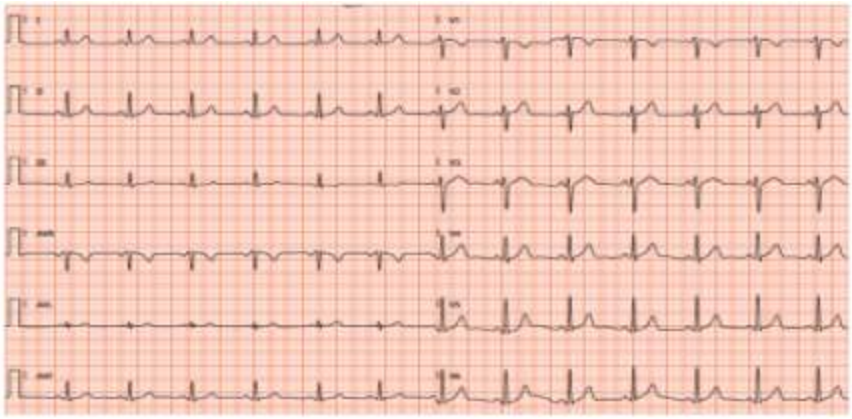

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Figure 18. ECG of a 23-year-old female recreational athlete who practices Nordic walking three hours a week, showing a PR interval of 106 ms without pre-excitation.

- **Prolonged QT interval**

Congenital long QT syndrome is a genetic disorder within the channelopathies group that poses a risk of sudden death due to ventricular arrhythmias.

In athletes, a prolonged QT interval is defined when the heart rate-corrected interval (QTc) is →470 ms in males and →480 ms in females (Bent et al., 2015). The Bazett formula, QTc = QT/√RR, is recommended for calculating QTc, with leads II and V5 providing the best assessment (Bazett, 2006).

Since the Bazett formula may underestimate the QTc duration at heart rates of <50 bpm, in these cases, it is recommended to repeat the ECG after physical exercise at light intensity (Sharma et al., 2017).

If a prolonged QTc interval is detected, the first thing we have to do is rule out reversible causes (drugs, electrolyte abnormalities, etc.) and review the personal history of syncope/presyncope and family history of syncope, unexplained dizziness or sudden death in patients under 50 years of age. If the personal or family history is positive, the athlete should be referred to a cardiologist specializing in electrophysiology for further study. Conversely, if the personal or family history is negative, we should repeat the ECG on different days and recheck the QTc interval. If this is normalized, nothing else is necessary; however, if it persists for a prolonged period, a family screening should be performed in first-degree relatives and the athlete should be referred to an electrophysiologist. If a prolonged QTc interval →500 ms is detected with no external cause to explain it, then the athlete should be referred directly to the electrophysiologist for further evaluation (Goldenberg et al., 2007).

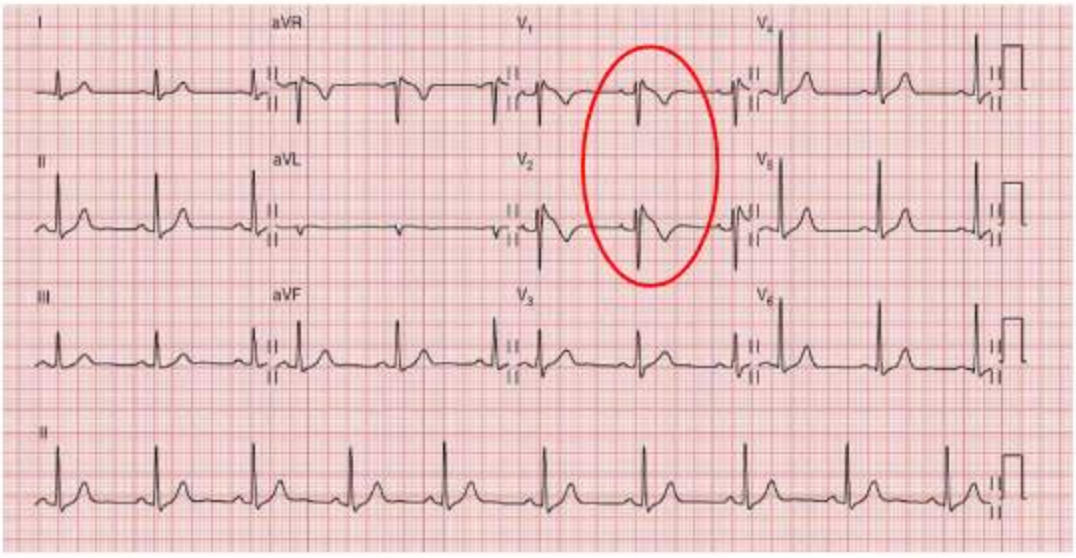
- **Brugada type 1 pattern**

Brugada syndrome is also a genetic disease within the group of channelopathies that increases the risk of sudden death due to ventricular arrhythmias, especially in situations with enhanced vagal tone.

It is characterized by the Brugada ECG pattern, which consists of the presence of rSr' along with a prominent concave ST-segment elevation →2 mm and T-wave inversion in V1, V2 and V3. There are three electrocardiographic patterns of Brugada; only type 1 is considered diagnostic (Bayes de Luna et al., 2012) (Figure 19).

When a Brugada type 1 ECG pattern is detected, make sure that V1 and V2 electrodes are correctly positioned in the fourth intercostal space. If so, another ECG should be performed placing these electrodes in the second intercostal space. If a Brugada type 1 pattern persists in this new ECG, the athlete should be referred to a cardiologist specializing in electrophysiology (Sharma et al., 2017).

Figure 19.



Source: own source.

Figure 19. ECG of a field hockey player, asymptomatic and with no family history, showing Brugada type I pattern with rSr' morphology in V1 and V2 followed by a prominent concave ST-segment elevation →2 mm and T-wave inversion.

- **Profound sinus bradycardia and first-degree atrioventricular block**

An HR <30 bpm or a PR interval →400 ms, although they may be physiological in well-trained athletes, should be investigated to rule out underlying heart disease. First, stress testing should be performed to analyze the response of the PR interval and HR with aerobic activity. If, when the subject is exercising, the PR interval normalizes and HR increases appropriately, and the subject is asymptomatic, no

further testing is necessary. However, further evaluation should include a transthoracic echocardiogram and a 24-hour Holter study if no increase in HR is observed or the PR interval persists prolonged, the subject presents syncope or presyncope, or in athletes with a family history of sudden death or heart disease.

- **High grade atrioventricular block**

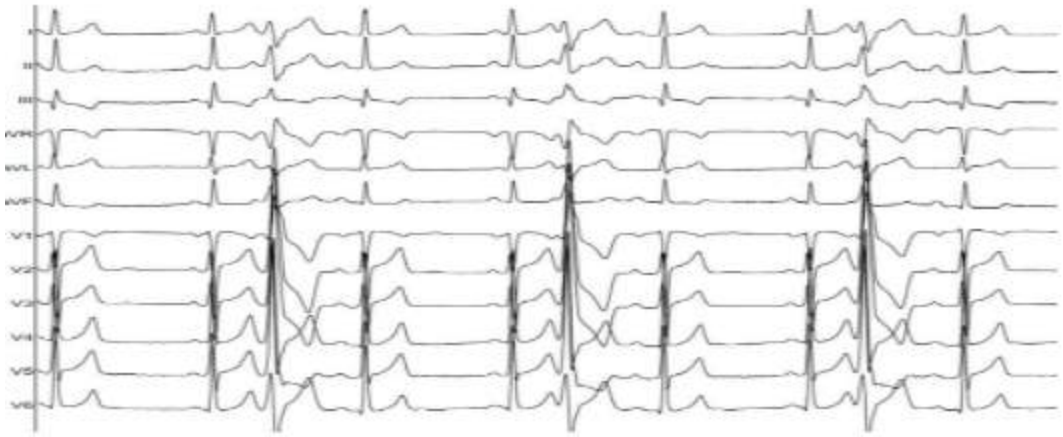
Type II second-degree atrioventricular block and third-degree or complete atrioventricular block are always considered pathological and should be studied by transthoracic echocardiogram, 24-hour Holter study and stress testing. Based on the results, cardiac MRI may be considered. In all cases, athletes must be referred to an electrophysiologist.

- **Multiple ventricular extrasystoles**

Although ventricular extrasystoles (VE) are usually benign, their finding may indicate the presence of heart disease (Biffi et al., 2002). They will be considered pathological when →2 VEs are detected in a 12-lead ECG (Figure 20). In this case, the evaluation will be completed by means of a 24-hour Holter, a transthoracic echocardiogram and a stress testing. If the 24-hour Holter and the echocardiogram show no alterations and the VEs are suppressed with exercise, it is not necessary to continue the study in asymptomatic individuals. If the Holter study detects >2000 VE within 24 hours and/or episodes of

non-sustained ventricular tachycardia are observed, or if stress testing shows an increase in VEs, a cardiac MRI and an electrophysiological study should be performed (Sharma et al., 2017).

Figure 20.



Source: own source.

Figure 20. Triathlon runner, 36-year-old, asymptomatic. The ECG is performed as part of the cardiovascular screening prior to sports practice, where two ventricular extrasystoles are detected, which must be considered as a pathological finding and compels us to complete the diagnostic study. Echocardiogram showed reduced left ventricular function (45%), and Holter ECG recording showed isolated ventricular extrasystoles of a morphology with a high arrhythmic burden (17%). The study was completed with an MRI that showed no

myocardial fibrosis. An ablation of the extrasystoles was performed successfully, with subsequent restitution of ventricular function.

- **Atrial tachycardias**

The finding of paroxysmal supraventricular tachycardia, atrial fibrillation or atrial flutter is considered pathological and should be studied.

If sinus tachycardia with HR 120 bpm is detected, the ECG should be repeated after a period of rest, and the presence of anxiety or other secondary causes, such as fever, anemia, dehydration, use of stimulant substances or hyperthyroidism, should be ruled out.

When faced with paroxysmal supraventricular tachycardia, we should try to suppress tachycardia by means of the Valsalva maneuver or carotid sinus massage in order to detect its mechanism. The study will then be completed with a transthoracic echocardiogram, a stress testing and a 24-hour Holter, and the athlete will be referred to the electrophysiologist for consideration of electrophysiological study and ablation of tachycardia.

If atrial fibrillation or flutter is found, a transthoracic echocardiogram will be indicated and the initiation of oral anticoagulant therapy will be considered based on relevant clinical practice guidelines. Based on the observations, completing the study with a cardiac MRI or

indicating an electrophysiological study and ablation can be considered.

- **Ventricular arrhythmias**

The presence of non-sustained ventricular tachycardias, ventricular couplets or triplets is always considered pathological, as it may indicate the presence of heart disease and carries a high risk of sustained ventricular tachycardia. In these cases, we should perform thorough family history evaluation, transthoracic echocardiogram, cardiac MRI, 24-hour Holter monitor and stress testing. Based on the observations, an electrophysiological study and/or genetic testing will be indicated.

Summary

Two summary tables are attached below with the characteristics of a normal ECG in athletes (Table 1), borderline findings (Table 2) and pathological findings (Table 3), together with the diagnostic tests indicated for each case.

CHARACTERISTICS OF A NORMAL ECG

All of these are considered variants of normal and do not prompt further diagnostic evaluation in asymptomatic individuals with no significant family history

FINDINGS	DEFINITION
Increased QRS complex voltage	LVH: S in V1 + R in V5 or V6 >35 mm RVH (right ventricular hypertrophy): R in V1 + S in V5 or V6 >11 mm
Incomplete right bundle branch block	rSR' in V1 + qRS in V6 and QRS <120 ms
Early repolarization pattern	J point →0.1 mV together with prominent T waves in inferior and/or lateral leads
Repolarization variant in Black people	J-point elevation + convex ST segment elevation in V1-V4 + T-wave inversion

Juvenile T-wave pattern (12-16 years old)	T-wave inversion/bi-phasic T wave in V1-V2
Sinus bradycardia	HR →30 bpm
Sinus arrhythmia (respiratory)	HR variation with respiration
Ectopic atrial rhythm	P waves with a different morphology with respect to sinus P waves.
Junctional escape rhythm	Frequency of QRS complexes > frequency P waves, usually <100 bpm
First-degree atrioventricular block	PR interval 200-400 ms
Second-degree atrioventricular block	PR interval becomes progressively longer

type I (Wenckebach) until a P-wave stops conducting

Table 1. Adapted from Serratosa-Fernández L., Pascual-Figal, D., Masiá-Mondéjar, MD., Sanz-de la Garza, M., Madaria-Marijuan, Z., Gimeno-Blanes, J. R., Adamuz, C.; Grupo de Cardiología del Deporte de la Sociedad Española de Cardiología. Comments on the New International Criteria for Electrocardiographic Interpretation in Athletes. Revista Española de Cardiología (English Ed.). 2017, Nov; 70(11):983-990.

Table 2. Borderline findings in the athlete's ECG

BORDERLINE CHARACTERISTICS
If they occur in isolation, no further studies are needed. The presence of 2 or more of these criteria requires a transthoracic echocardiogram to rule out underlying heart disease.

FINDINGS DEFINITION	
Electrical left axis deviation -90º	QRS axis -30º to
Electrical right axis deviation	QRS axis >120º
Left atrial enlargement >120 s in leads I or II	P wave duration
of the P wave → 1 mm	with the negative portion
→40 ms duration in V1	in depth and
Right atrial enlargement →2.5 mm in leads II, III or aVF	P wave

Complete right bundle branch block	rSR' pattern in V1 and S-wave >R in V6 with a QRS duration >120 ms

Table 2. Adapted from Serratosa-Fernández L., Pascual-Figal, D., Masiá-Mondéjar, MD., Sanz-de la Garza, M., Madaria-Marijuan, Z., Gimeno-Blanes, J. R., Adamuz, C.; Grupo de Cardiología del Deporte de la Sociedad Española de Cardiología. Comments on the New International Criteria for Electrocardiographic Interpretation in Athletes. Revista Española de Cardiología (English Ed.). 2017, Nov; 70(11):983-990.

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