Specific Cardiovascular Diseases and Competitive Sports Participation: Arrhythmias

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Learning Objectives

1. Learn to distinguish those cardiac rhythm disorders which are the expression of physical training and do not have significant clinical impact (such as sinus bradycardia, low degree AV block etc.).
2. Give attention to the atrial and ventricular arrhythmias which may have a malignant consequence on athlete careers.
3. Set up a correct and appropriate diagnostic work up using modern and useful diagnostic tools.
4. Learn the decision-making protocols to grant sports eligibility and follow-up in athletes with arrhythmias.

17.1 Introduction

Arrhythmias represent a common finding in the evaluation of the athlete. They can be the expression of a benign phenomenon, such as bradyarrhythmias due to an increase of the vagal tone or raise the clinical suspect of an underlying heart disease, such as ventricular arrhythmias. In this chapter, we summarize the most frequent arrhythmias that can be encountered in athletes and the criteria for sports eligibility.

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A. Pressler, J. Niebauer (eds.), *Textbook of Sports and Exercise Cardiology*,
https://doi.org/10.1007/978-3-030-35374-2_17

17.2 Sinus Bradycardia and Atrio-Ventricular Conduction Disturbances

17.2.1 Sinus Bradycardia, Sinus Arrhythmia and Sinus Pauses

Sinus bradycardia is a non-pathologic condition that represents a common feature of the athlete's heart as a consequence of the increased vagal tone [1]. Its prevalence varies widely among the populations oscillating from 4% to 8% in non-athletes, and from 40% to 90% in athletes according to the degree of training [1–5]. Sinus pauses > 2 s at 24-h ambulatory electrocardiogram (ECG) monitoring are also quite common and are observed in more than one third of athletes [6]. Sinus rates at rest in the 40–50 bpm range are common in endurance athletes [1–6].

- In highly trained athletes, even marked sinus bradycardia may be observed (<40 bpm), without pathological significance.
- Conversely, in athletes practicing sport at low cardiovascular intensity, a daytime resting heart rate (HR) <40 bpm is infrequent and potentially pathological.

With significant sinus bradycardia, a junctional or ventricular escape rhythm can compete with the sinus rhythm. Sinus arrhythmia and wandering atrial pacemaker are also more prevalent in athletes compared with the general population.

Sports eligibility can be granted in athletes without heart disease and without bradycardia-related symptoms (syncope, pre-syncope, dizziness, dyspnea, etc.).

- In cases of athletes with marked sinus bradycardia, exercise testing (ET) should show a normal chronotropic response (achievement of at least 85% of maximum theoretical heart rate for age) and 24-h ambulatory ECG monitoring should not record pauses >3 s.
- In athletes practicing aerobic sports, sinus pauses >3 s should not be considered as a sign of sinus node dysfunction, as long as they are not associated to symptoms or arrhythmias correlated with bradycardia.
- In selected case, 3–6 months of detraining can be very useful in documenting the significant reduction of the sinus arrhythmia or pauses, as expression of vagal tone.

17.2.2 Atrioventricular Block (AVB)

First-degree and second-degree type 1 AVB are not rare in athletes practicing aerobic sports and are also considered a major expression of adaptation to physical training, while Mobitz type II second-degree AVB and third-degree AVB are very rare and often pathological [7–11]. Second-degree type 1 AVB is frequently

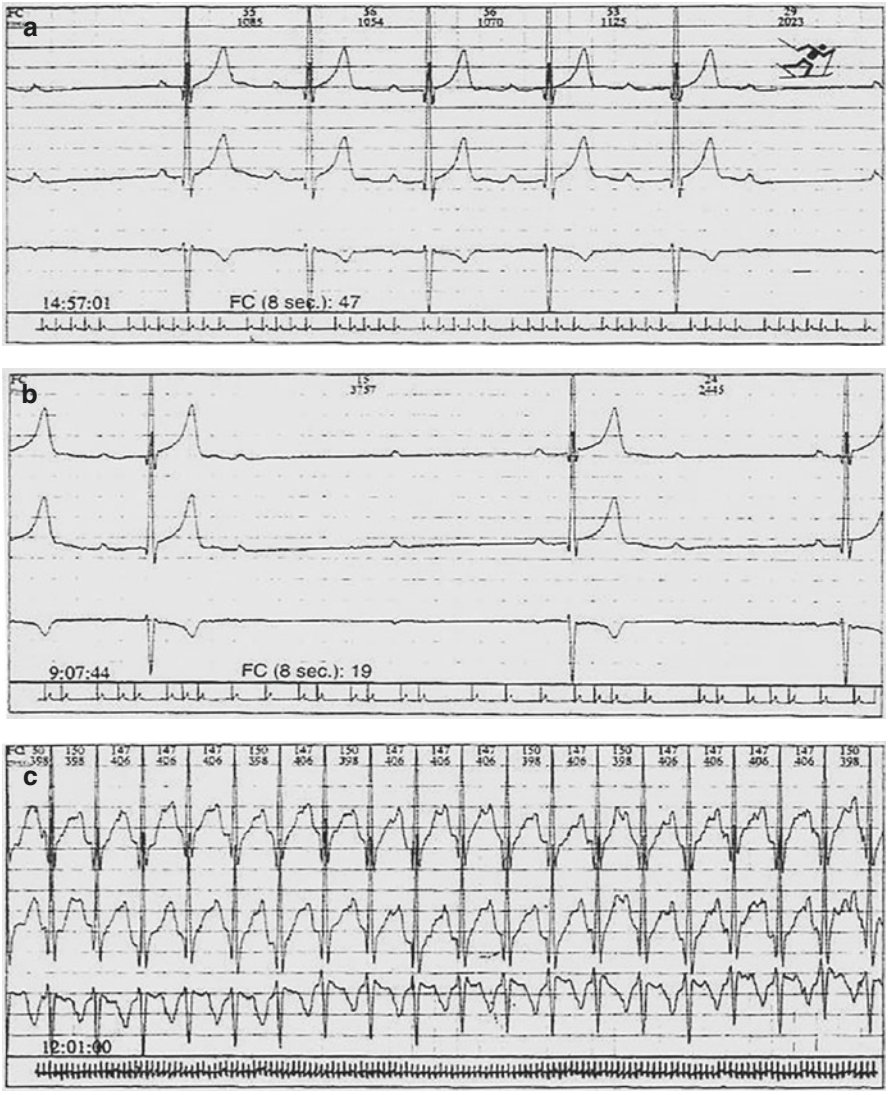

Fig. 17.1 Cross-country skier, 28 years old, with asymptomatic resting/nocturnal Mobitz-1 atrio-ventricular block (**panel a**), occasionally advanced (3:1; **panel b**). The atrio-ventricular conduction disturbance is completely normalized by physical exercise (**panel c**)

observed during nighttime (i.e. when the vagal tone is highest) at 24-h ambulatory ECG monitoring, but it may rarely be observed at rest during daytime. Both first-degree and second-degree type 1 AVB should normalize during exercise or hyperpnoea (Fig. 17.1). On the other hand, appearance of an AVB during exercise is always pathological, suggesting an infra-hissian block (i.e. secondary to a disease of the conduction system).

17.2.3 Sports Eligibility

- First-degree AVB, which disappears during exercise or hyperventilation, does not contraindicate any sports activity.
- In second-degree AVB with narrow QRS and Luciani-Wenckebach periodism (Mobitz type-1), eligibility is granted in the absence of heart disease or symptoms and in the case of normalization of the atrioventricular conduction with the increase in HR during ET.
- Second-degree AVB Mobitz type-2, advanced and complete AVB require investigation of the conduction system by invasive electrophysiologic study [12].
  - If a disease of the cardiac conduction system is excluded and the AVB is considered to be secondary to hypervagotonia, they may be compatible with sports if the atrioventricular conduction normalizes during ET, no prolonged (>3 s) ventricular pauses are recorded at 24-h ambulatory ECG monitoring and the athlete is asymptomatic.
  - Persistent forms and those unrelated to physical training contraindicate sports activity.
  - In controversial cases, re-evaluation after 3–6 months of detraining may be useful.

17.3 Supraventricular Arrhythmias

17.3.1 Premature Atrial Beats

The presence of occasional premature atrial beats can be considered a common finding in healthy athletes. Frequent and/or repetitive premature atrial beats require further diagnostic testing, such as ET and echocardiography to rule out an underlying heart disease. Electrolytes and thyroid function should also be checked.

Sports eligibility may be granted in the absence of significant symptoms or underlying heart disease.

17.3.2 Paroxysmal Supraventricular Tachycardias (with No Overt Pre-Excitation)

Atrio-ventricular nodal re-entrant tachycardia (AVNRT) and orthodromic atrioventricular re-entrant tachycardia (ARVT) through a concealed accessory pathway are the two most common paroxysmal supraventricular tachycardias in young people [13]. Although benign, these arrhythmias may be poorly tolerated in athletes because they may occur during sports activity, and sympathetic stimulation increases their HR.

As a consequence, *sports eligibility* can be granted only if there is:

- no history of severe symptoms and the recurrences are rare and non-exercise related.

- In the other cases, catheter ablation is the best option, given the very high success rate (approximately 90% for AVRT and >95% for AVNRT) and the low risk of complications [14].
  - One month after successful ablation, in the absence of complications and recurrences, the athlete can resume competitions [15].

17.3.3 Wolff-Parkinson-White Syndrome

Wolff-Parkinson-White (WPW) syndrome is a congenital heart disease characterized by the abnormal persistence of a muscular bundle (accessory atrioventricular pathway) which provides an alternative way of electrical connection between atrial and ventricular myocardium, other than the normal atrioventricular node-His bundle axis [14, 15]. Typical ECG features of ventricular pre-excitation in the WPW syndrome include:

1. a PR interval less than 0.12 s
2. with a slurring of the initial segment of the QRS complex, known as a delta wave, and
3. a QRS complex widening with a total duration greater than 0.12 s.

The delta wave may be particularly evident in highly trained athletes who exhibit an increased vagal tone and prolonged atrioventricular node conduction time.

The WPW syndrome may be complicated by different types of arrhythmia, in particular:

(a) AVRT, either orthodromic or antidromic and
(b) pre-excited atrial fibrillation (AF) that can degenerate into lethal ventricular fibrillation in case of very rapid atrioventricular conduction through the accessory pathway.

Physical activity may increase the occurrence of arrhythmias in WPW syndrome [14, 15]. As the risk of sudden death is proportional to the ability of the accessory pathway to provide fast atrioventricular conduction in case of AF, evaluation of the accessory pathway refractoriness by transesophageal or endocavitary electrophysiological study is a prerequisite for sports eligibility. The study can be avoided in asymptomatic patients with intermittent delta wave and can be delayed in asymptomatic children aged <12 years who are at very low risk of sudden death [15].

Sports eligibility should be granted only in athletes

- with no history of supraventricular arrhythmias and
- if the electrophysiology study demonstrates a refractory period of the accessory pathway ≥250 ms at rest and ≥210 ms during exercise or isoproterenol infusion.

In case of previous symptoms or high-risk accessory pathway, the athlete should be referred for catheter ablation [15].

17.3.4 Atrial Fibrillation and Atrial Flutter

The association between sports activity and the risk of developing AF has been evaluated by several studies that have provided different results depending on the age, years of training, and type of sport of the study population [15–28]. Overall, these studies suggest that moderate intensity physical activity is associated with a lower incidence of AF, but high-intensity endurance sports increases the risk of AF in middle-aged athletes but not in younger individuals (see also Chaps. 34 and 51). The pathophysiological mechanisms responsible for the development of AF in athletes remain speculative and are mostly dependent on experimental data. Atrial enlargement and fibrosis, increased atrial ectopy, increased vagal tone and changes in electrolytes have been proposed as possible mechanisms [29].

Because AF in athletes usually occurs in the context of a structurally normal heart ("lone AF") and because anti-arrhythmic drugs may be poorly tolerated, pulmonary vein isolation by catheter ablation is been increasingly offered to athletes as a first line therapeutic option [30, 31]. Although observational studies suggest that the outcome of AF ablation in athletes is similar or better than in sedentary individuals, long-term arrhythmia-free survival after a single procedure ranges 50–70% and repeat ablations are required to achieve a 70–80% probability of freedom from AF [32–35]. Moreover, the rate of serious complications is not negligible (1–5%) and it has to be discussed with the patient before this strategy is chosen [36].

Sports eligibility in athletes with paroxysmal AF may be granted

- in the absence of structural heart disease,
- if the episodes are sporadic,
- not exercise-induced and
- not associated with severe symptoms.

Permanent AF usually contraindicates competitive sport at medium or high cardiovascular demand. In case of one of more risk factors for AF-related arterial thromboembolism (such as age > 65 years old, hypertension and diabetes) anticoagulation therapy should be considered and, if this is initiated, sports at-risk for trauma should be avoided because of the risk of bleeding.

Atrial tachycardia and atrial flutter are uncommon in athletes without heart disease and may cause elevated heart rates during exercise. Therefore, such arrhythmias are not usually compatible with athletic activity at medium-high cardiovascular intensity. Catheter ablation of the cavo-tricuspidal isthmus is a highly effective and safe therapy for the treatment of typical atrial flutter and should thus be considered as the treatment of choice [37].

17.4 Ventricular Arrhythmias

In the majority of cases, ventricular arrhythmias that may be encountered in athletes consists of simple premature ventricular beats (PVBs) resulting from the activity of a benign and idiopathic automatic focus that is usually suppressed by exercise,

similarly to the sedentary population [38]. Only occasionally, idiopathic PVBs may increase in number and complexity during effort and cause non-sustained or sustained ventricular tachycardia that may be fast enough as to cause severe symptoms such as syncope [30, 31, 39], or be numerous enough as to cause PVBs-mediated left ventricular dysfunction [40]. Rarely, PVBs may represent the clinical manifestation of an underlying heart disease potentially at-risk of sudden cardiac death. Hence, the first objective in evaluating an athlete with ventricular arrhythmias is to exclude life-threatening cardiovascular diseases [41].

17.4.1 Features that may Suggest an Underlying Heart Disease

An increase in the arrhythmia at the beginning of exercise, disappearance at peak exercise, and reappearance during recovery usually suggest a benign process [38]. On the other hand, triggering or worsening of the arrhythmia during exercise may indicate an underlying cardiomyopathy or ion channel disease [42–49].

Careful assessment of the morphology of the arrhythmic QRS complex may help to identify the anatomic origin and the probability of an underlying disease:

- The most common benign PVBs of the athletes show a negative QRS complex in V1 (left-bundle-branch-block, LBBB pattern) and inferior axis in the limb leads (positive QRS complex in II, III and aVF), indicating origin from the ventricular outflow tract (either right or left).
  - Also, ventricular arrhythmias with a slightly prolonged QRS (0.12–0.13 s) and a morphology of the ectopic QRS resembling a typical right-bundle-branch-block (RBBB) in V1 suggests the origin from a fascicle of the left bundle and are usually benign.
- In contrast, arrhythmias with different configurations such as LBBB and intermediate/superior axis or RBBB with wide QRS are rarer in healthy athletes and may be the sign of an underlying structural heart disease [40–47] (Fig. 17.2).
  - In particular, PVBs with a RBBB configuration indicate a left ventricular origin and suggest possible left ventricular diseases such as
    dilated/inflammatory cardiomyopathy,
    hypertrophic cardiomyopathy,
    left ventricular non-compaction, or
    a predominantly left-sided arrhythmogenic cardiomyopathy (ARVC),

particularly if the arrhythmia increases in number and complexity with increasing workload during ET [39, 48].

The prevalence of concomitant repolarization/depolarization ECG abnormalities increases the probability of an associated disease. The association between PVBs with a LBBB pattern and repolarization abnormalities, such as T-wave inversion in the right precordial leads is highly suggestive of ARVC. The coexistence of a right ventricular conduction defect in the form of a prolonged QRS duration or a delayed S-wave upstroke in V1–V3 further increases the likelihood of ARVC [49].

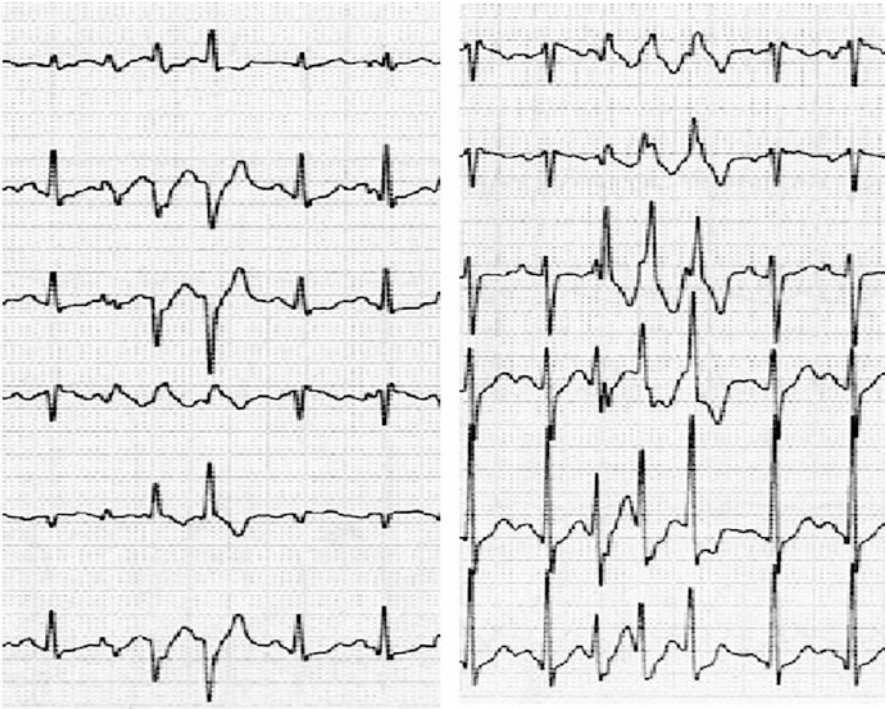

Fig. 17.2 Swimmer, 26 years old, with a brief episode of exercise-induced non-sustained ventricular tachycardia. The ventricular arrhythmia has an uncommon morphology with wide right bundle branch block. Constrast enhanced cardiac magnetic resonance showed the presence of a subepicardial left ventricular scar

Finally, the induction of polymorphic VT during exercise always carries a bad prognosis. Polymorphic VT with alternating complexes ("bidirectional" pattern), induced during exercise, suggests the inherited ion channel disorder, catecholaminergic polymorphic ventricular tachycardia, which causes exercise-induced arrhythmic cardiac arrest in the absence of structural heart disease as discussed above [50].

17.4.2 Work-Up of Athletes with Ventricular Arrhythmias

The work-up of athletes with ventricular arrhythmias should always include

(a) echocardiography,
(b) 24-h ambulatory ECG monitoring and
(c) ET.

Ambulatory ECG monitoring should include a training session and, possibly, have a 12-lead configuration that allows to evaluate the PVBs morphology. Exercise tests should mimic the exercise/sport practiced by the patient, because a

conventional ET may not replicate the specific clinical situation and the arrhythmogenic mechanisms produced by the sport. Echocardiography is the preferred imaging modality in the evaluation of athletes with ventricular arrhythmias in order to exclude an underlying a cardiomyopathy or a congenital heart disease. However, even if echocardiography is negative, contrast-enhanced cardiovascular magnetic resonance imaging may be particularly indicated in athletes with complex and/or exercise-induced PVBs with a RBBB configuration and wide-QRS, in order to exclude concealed left-ventricular scar tissue that may be a substrate for life-threatening ventricular arrhythmias and sudden cardiac death in the athlete [39, 48].

In selected athletes in whom non-invasive clinical and instrumental findings are inconclusive, other invasive tests such as

(a) electrophysiological study,
(b) coronary angiography (particularly in older athletes with coronary risk factors), and
(c) endomyocardial biopsy

may be required to achieve a definite diagnosis. Molecular genetic studies are increasingly available for the diagnosis of inherited arrhythmogenic heart muscle diseases, including channelopathies, and are particularly indicated if catecholaminergic polymorphic ventricular tachycardia is suspected (see Chap. 12). Work-up should also include a search for agents that may enhance electrical ventricular irritability, such as the use of excessive amount of alcohol, illicit drugs, or stimulants, particularly ephedrine and caffeine (see Chap. 28).

17.4.3 Sports Eligibility in Athletes with Premature Ventricular Beats

- The 2006 consensus document of the Working Group on Sports Cardiology of the European Society of Cardiology recommended to exclude from competitive sports activity athletes with >2000 PVBs/day, repetitive or exercise-induced PVBs even in the absence of an underlying structural heart disease, unless they disappear after 3–6 months of detraining [51].
  - However, these recommendations appear out-of-date considering the current perspective on the clinical meaning of PVBs based on more recent scientific data.
- The 2015 recommendations of the American Heart Association/American College of Cardiology suggest that athletes with PVBs and no underlying disease can participate in all competitive sports.
  - However, when PVBs increase in frequency during exercise or exercise testing and convert to repetitive forms, further evaluation by appropriate imaging or monitoring strategies is recommended before clearance for participation in high-intensity sports.
  - If exercise-induced arrhythmias cause symptoms, the athlete should be limited to exercise below the level at which arrhythmias occur.
  - Conversely, athletes with defined structural heart disease should be limited to low-intensity competitive sports.

- Finally, according to the 2017 recommendations of the Italian Society of Sports Cardiology, athletes with PVBs should be carefully assessed for an underlying heart disease.
  - The work-up should include cardiac magnetic resonance in case of PVBs with a left ventricular origin.
  - In case no disease is detected, the athlete is considered eligible to competitive sports activity in the absence of severe symptoms, complex arrhythmias (short-coupled PVBs or narrow couplets) or PVBs-induced left ventricular dysfunction [52].

17.4.4 Ventricular Tachycardia

Ventricular tachycardia (VT) can be either non-sustained (3 or more beats but lasting less than 30 s) or sustained (>30 s) and not leading to hemodynamic deterioration. Similar to PVBs, VT may be idiopathic and result from the activity of an ectopic focus or be secondary to a heart disease.

Benign idiopathic VTs include fascicular VT and ventricular outflow tract VT. These VTs are usually well tolerated but if they occur during exercise, they can show a high heart rate and lead to syncope [53, 54].

Consequently, *sports eligibility* can be granted only in cases there is

- no underlying heart disease (particularly arrhythmogenic cardiomyopathy),
- the athlete is asymptomatic, and
- the episodes are sporadic, of short duration, with low heart rate and unrelated to exercise.

In the other cases, catheter ablation is the preferred therapeutic option.

The occurrence of monomorphic sustained VT (>30 s) other than fascicular and infundibular, polymorphic VT, torsades de pointes, and/or cardiac arrest due to ventricular fibrillation, contraindicate both competitive and recreational sports activity. The only exceptions are VT arising in the context of acute and fully reversible disease with a low probability of recurrence, such as myocarditis, electrolyte disturbances and intake of drugs. In these cases, suspension of physical activity for 3–6 months and subsequent cardiovascular reassessment is recommended [51].

Clinical Pearls

- Due to an increased vagal tone, trained athletes commonly develop benign rhythm and conduction disturbances including sinus bradycardia, junctional rhythm, first-degree and second-degree Mobitz type-I atrioventricular block.
- These alterations usually disappear with adrenergic stimulation during exercise and do not preclude sports participation.
- Paroxysmal supraventricular tachycardia and atrial fibrillation usually occur in athletes with a structurally normal heart but may be incompatible with

competitive sports activity in case of severe symptoms or exercise-dependent episodes.

- Ventricular arrhythmias ranging from isolated premature ventricular beats to ventricular tachycardia require careful clinical investigation aiming to exclude an underlying structural heart disease potentially at risk of sudden cardiac death before the athlete can safely engage in high-intensity exercise.

Review

Questions

1. Top-level athlete, male, 28 years old, practicing soccer from 15 years, asymptomatic, without family and personal history for cardiovascular disease, presenting with a second-degree, type 1 atrio-ventricular block during resting 12-lead ECG. What examination may be useful to guarantee his sport eligibility?
2. Volleyball player, male, 27 years old, without clinical history of sudden death, asymptomatic, during pre-participation screening; occurrence of exercise-induced ventricular arrhythmias during an exercise stress test, sometimes as couplets, with RBBB morphology and wide QRS complex. What further examinations do you suggest?
3. 24 years old, male tennis player, presenting with paroxysmal palpitations and resting ECG showing a supraventricular tachycardia at HR 220 bpm, with narrow and regular QRS. The tachycardia has a spontaneous interruption after 10 min. When sinus rhythm is restored, ECG shows the presence of an overt ventricular pre-excitation. Can the athlete be considered eligible for competitive sports activity at this point?

Answers

1. Exercise stress testing (EST) is the first exam to confirm the physiological, adaptive response of atrio-ventricular node to exercise training. EST usually normalizes the atrio-ventricular conduction during exercise and recovery phase. Also 24-h Holter ECG monitoring, including a training session, could be useful to verify the normalization of AV conduction during an exercise session and to show the maximal expression of AV disturbances during night sleeping.
2. The arrhythmia morphology (RBBB with wide QRS) is uncommon and could be associated with a concealed arrhythmogenic substrate, such as left ventricular scar. Therefore, beyond carrying out colour-doppler echocardiogram and 24-h Holter ECG monitoring, also contrast enhanced cardiac magnetic resonance, with tissue imaging typing, is requested.
3. No. Symptomatic WPW syndrome is not compatible with competitive sports activity. The athlete can be considered suitable for RF catheter ablation.

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