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PATHOLOGIES IN TEAM SPORTS

THE HEART AND SPORTS

➔ 2.1 Cardiac Pathology

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Sudden cardiac death and sports: the magnitude of the problem, its causes and strategies for prevention

The prevalence of sudden cardiac death (SCD) in sports is relatively low, with an annual rate of 1-2 deaths per every 100,000 athletes (Sharma, Estes, Vetter, & Corrado, 2013). Nevertheless, such deaths garner a lot of public attention due to the fact that they are unexpected, occur in young people, and also clash with the idea that exercise is part of a healthy lifestyle.

In a practical approach to this problem, *the rule of 5* for SCD in sports has been coined, because it represents 5% of the total incidence of SCD in the general population (Marijon et al., 2015). SCD occurs in 5% of females (Bohm, Scharhag, & Meyer, 2016), and 5% of competitive athletes; however, the latter register a relative risk that is five times greater than those who practice sports recreationally (Marijon et al., 2011).

Estimations of the prevalence of SCD has differed in the different populations studied across Europe (Corrado, Basso, Rizzoli, Schiavon, & Thiene, 2003; Manonelles Marqueta et al., 2007; Marijon et al., 2011; Finocchiaro et al., 2016) or North America (Maron, Doerer, Haas, Tierney, & Mueller, 2009). This variation is explained by three main points: a) the epidemiological characteristics of each region; b) the average age of the individuals; and c) the different records or methods used to obtain the data, which is the main reason for these differences in prevalence rates.

A meta-analysis of the cited studies produced the following results on the causes of SCD during sports practice:

Table 1: Causes of sudden death in sports.

<i>Causes of sudden death in sports</i>	%
Hypertrophic cardiomyopathy	30
Coronary artery abnormalities	15
Left ventricular hypertrophy	11
Arrhythmogenic dysplasia of the right ventricle	6
Myocarditis	5
Aorta abnormalities	5
Early coronary disease	5
Other causes	23

Source: Prepared by the author.

Sports that involve acyclic exercise, that is, sports that involve a rapid increase in heart rate, record a higher number of sudden deaths; however, this is also variable depending on the country being analyzed. One example is American Football, which has the highest prevalence of SCD in North America (Maron et al., 2009).

The pre-participation screening model suggested by the European Society of Cardiology (Corrado, 2005) has been proposed as a primary prevention method for sudden death in sports and is the most used model worldwide. It consists of: 1) the patient's family and personal history; 2) a physical examination; 3) a 12-lead electrocardiogram (ECG). The physician will follow this with a second phase if the basic screening picks up any abnormalities. Further tests include an echocardiogram, a stress test, a 24-hour Holter-ECG, a cardiac magnetic resonance or an electrophysiology study. The objective is to identify diseases that have the potential to cause SCD in sports. The recommended model in the USA does not include an ECG, and is solely based on the patient's medical history and a physical examination. This model lacks scientific evidence to support its use due to its limited sensitivity.

There are two main elements to secondary prevention of SCD in sports: a medical action plan and an automated external defibrillator, as recommended by the Fédération International de Football Association or FIFA (Dvorak, 2013). For prevention to be efficient, prior and annual training of the individuals responsible in this regard, and automatic communication between the defibrillator and the local emergency services that provide advanced life support are essential.

The following table summarizes the most important aspects of SCD and its prevention in athletes:

Table 2: Sudden Cardiac Death.

Incidence	Main causes	Primary prevention	Secondary prevention
1-2 in 100,000 athletes/year	-Hypertrophic cardiomyopathy -Coronary heart disease -Coronary artery abnormality	Pre-participation screening -Family and personal history -Physical examination -ECG	-Medical action plan -Automated external defibrillator

Source: Prepared by the author.

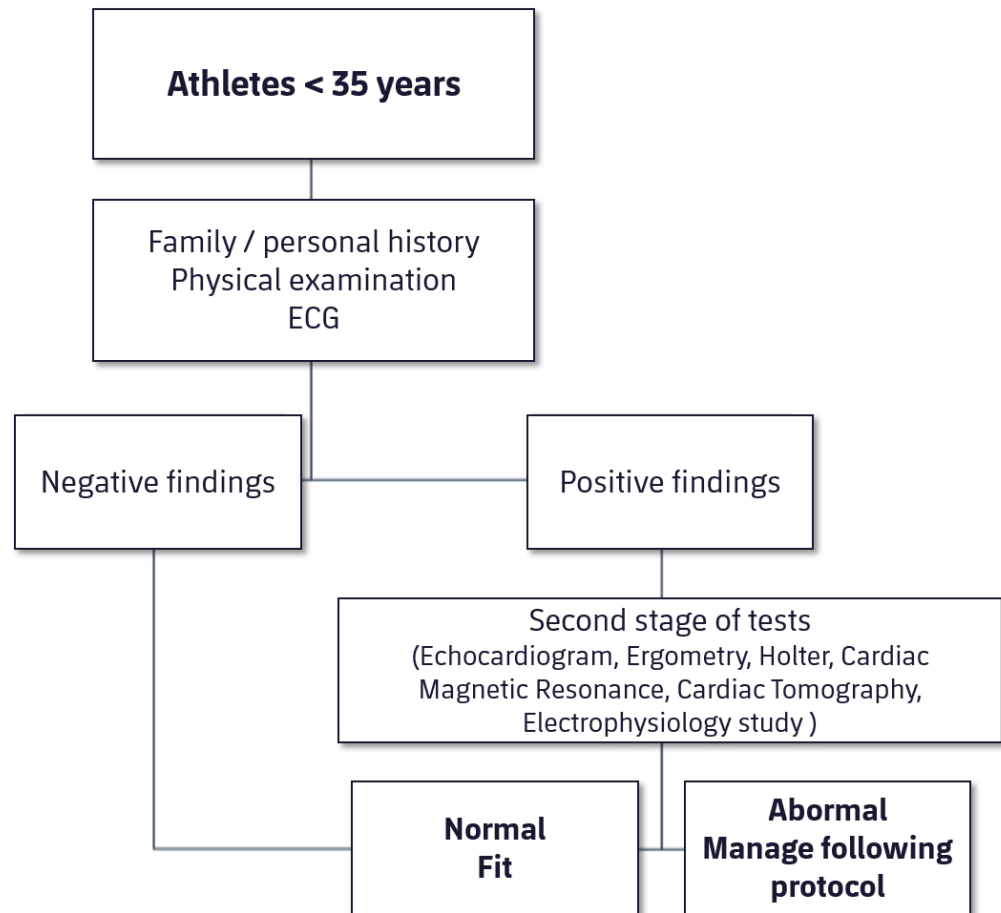
Pre-participation screening: uses and methodology

The prevention strategy for sudden death in sports (through the pre-participation screening to identify diseases that can cause sudden death) differs depending on geographical location. There are two models, one which includes the use of an electrocardiogram and one which does not: 1) the American model includes family and personal history and a physical examination (Maron et al., 2015) and 2) the European model, in addition to the previous steps, adds the 12-lead ECG (Corrado et al., 2005). There is debate regarding the usefulness of electrocardiograms due to false positives and their cost-benefit ratio (Sharma et al., 2017).

The accepted limit in international literature is 35 years, because atherosclerotic coronary disease becomes the main cause of sudden death as of this age, occurring at rates at least four times higher than in the other etiologies (La Gerche et al., 2013). SCD in people aged 35 and under is mainly due to congenital heart diseases that generate complex arrhythmias. This is the direct cause of death when SCD occurs during exercise, while in the over 35 age group, ischemic heart disease is the main cause.

The European Society of Cardiology published an expert consensus in 2005, based largely on pre-participation screenings carried out in Italy (Corrado, D., Basso, & Andrea, 2006). The first stage of a pre-participation screening includes family and personal history, the physical examination and the 12-lead ECG (Figure 1). In cases where there was an abnormality, a second stage was activated whereby further complementary tests were requested such as the Doppler echocardiogram, cardiac magnetic resonance or a CT scan of the coronary arteries, as well as tests that examine electrical conductivity, such as the stress test, the 24-hour Holter-ECG or an electrophysiology study. Currently, the recommendation to include an ECG in pre-participation screenings has been adopted in all European Union countries, although there are differences in the compulsory nature of the second stage of testing (Corrado et al., 2011). In athletes over age 35, the first step is to measure their physical activity, valued in METs (Metabolic Equivalent of Task) per hour per week, a symptoms questionnaire and the European cardiovascular risk score that covers traditional risk factors such as: age, sex, total cholesterol, blood pressure and tobacco consumption, to decide if it is necessary to perform a stress test (Borjesson et al., 2011).

Figure 1: Pre-participation screening recommended by the European Society of Cardiology

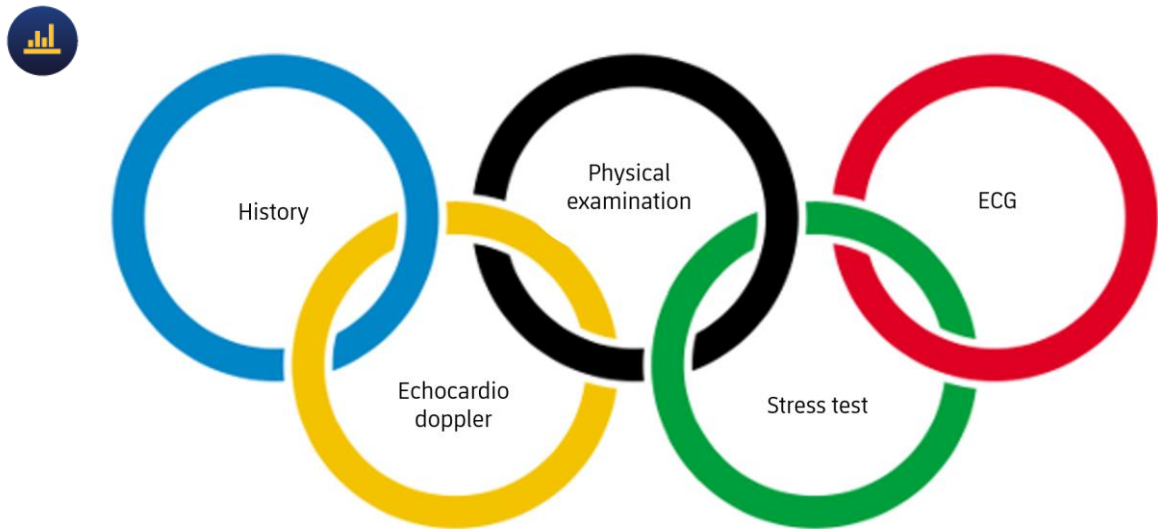


Source: adapted from Corrado et al., 2005.

In Catalonia, which follows the European model, it is suggested that all athletes undergo the three main processes (Sitges et al., 2013; Figure 2), which are: a) the family and personal history; b) the physical examination (both in accordance with the 12-point model proposed by the American Heart Association (Maron, Douglas, Graham, Nishimura, & Thompson, 2005); c) the electrocardiogram. Additional tests, that is, the Doppler echocardiogram and stress test, are routinely applied to the following athletes: competitive athletes or those who subject their bodies to intense physical demands (Mitchell III-C), as well as athletes over the age of 35. The aim of these additional tests is to improve diagnosis sensitivity in individuals with hypertrophic cardiomyopathy and normal ECGs with anomalies in the origin of the coronary arteries or with a dilated aortic

root. All of this is to improve diagnostic sensitivity in coronary heart disease and cardiac arrhythmias that are revealed during exercise. This screening model has proven to be cost-effective when analyzing a population of competitive adolescent athletes (Grazioli et al., 2017).

Figure 2: Schematics of the pre-participation screening recommended in Catalonia.



Source: Sitges et al., 2013

The athlete's electrocardiogram

Regular sports activity produces a series of morphological and functional changes in the human heart that can be observed in an electrocardiogram, with very diverse changes. Such changes will depend of age, gender, ethnicity and the type, intensity and duration of training, as well as the individual's sports history. The European Society of Cardiology (ESC) recommends that an ECG be performed (Mont et al., 2017) along with the clinical history and physical examination, as part of an athlete's cardiovascular screening, due to the ECG's ability to detect cardiomyopathies and channelopathies, as well as its cost effectiveness. Thus, it is essential that the physicians involved in the athlete's screening are able to correctly interpret the results (Serratosa Fernández et al., 2017).

New criteria for interpreting an athlete's ECG has been published recently (Drezner et al., 2017). In these criteria, ECG findings are classified as normal, borderline and abnormal (see Table 1).

Normal findings include sinus bradycardia, prolonged PR interval, second-degree atrioventricular block (Mobitz I), an ectopic or wandering atrial rhythm and a nodal escape rhythm. These results are considered to be physiological responses to exercise and it is only recommended that it be verified that they are resolved with exercise. An incomplete right bundle branch block is considered to be a sign of training adaptation. Any pattern of early repolarization and the presence, in black athletes, of negative T waves in leads V1 to V4 preceded by J-point elevation and convex ST-segment elevation, when they occur in an isolated manner without any other clinical or electrocardiographic data suggestive of disease, do not require additional assessment (Serratosa Fernández et al., 2017).

Borderline findings include the following: left or right axis deviation, right or left atrial growth and complete right bundle branch block (Kim et al., 2011). The appearance of any of the above in an isolated way does not suggest a pathology, but the combined appearance of at least two of these requires additional testing (Serratosa Fernández et al., 2017).

The following abnormalities, if detected in an ECG, are signs of an underlying heart disease: T-wave inversion (TWI) is one of the most clinically important findings in an athlete's ECG (Schnell et al., 2015). The pathological repercussions are determined by its location and the athlete's gender, age and ethnicity. A 0.05 millimeter ST depression in two or more contiguous leads, the presence of Q waves, complete left bundle branch block (Kim, & Baggish, 2015), a QRS duration greater than 140 ms and the presence of an epsilon wave all rule out structural heart disease. Other findings that may indicate a channelopathy include: a prolonged corrected QT interval (QTc of 470 msec in men and 480 msec in women) and a type 1 Brugada syndrome pattern. Other findings subject to further testing are rhythm abnormalities, including: severe sinus bradycardia (less than 30 bpm), a PR interval of 400 ms, second degree (Mobitz II) or third degree AVB, ventricular preexcitation (PR below 120 ms and presence of a delta wave), the presence of two ventricular extrasystoles in an ECG, atrial tachyarrhythmias (supraventricular tachycardia, fibrillation or atrial flutter) and, last but not least, ventricular tachycardias (Serratosa Fernández et al., 2017).

Table 3: Summary of normal, abnormal and borderline findings in the interpretation of an athlete's ECG according to the 2017 international consensus

Normal ECG findings Do not require additional evaluation	
QRS voltage criteria for right or left ventricular hypertrophy	
Incomplete right bundle branch block	
Early repolarization	
ST elevation followed by R-wave inversion in V1-V4 in black athletes	
Inverted T wave in V1-V3 in children under 16 years of age	
Bradycardia or sinus arrhythmia	
Ectopic atrial or junctional rhythm	
1st or 2nd degree AVB (Mobitz I)	
Borderline ECG findings The presence of two or more of these findings requires additional assessment	
Right axis deviation	
Right atrial growth	
Left axis deviation	
Left atrial growth	
Complete right bundle branch block	
Abnormal ECG findings Require additional evaluation	
Inverted T wave	

ST segment depression
Pathological Q waves
Complete left bundle branch block
QRS duration greater than 140 msec
Presence of epsilon wave
Ventricular preexcitation
Prolonged QT interval
Type 1 Brugada syndrome pattern
Severe sinus bradycardia (less than 30 bpm)
PR interval → 400 ms
Second degree AVB (Mobitz II)
3rd degree AVB
→ 2 Ventricular extrasystoles
Atrial tachyarrhythmias
Ventricular tachyarrhythmias

Source: adapted from Serratosa Fernández et al., 2017.

Other cardiological diagnostic tests for athletes

If there are signs and symptoms suggestive of heart disease in the initial cardiovascular screening, the physician must investigate further to rule out or confirm the presence of an underlying cardiac pathology. The most useful cardiovascular diagnostic tests for a more precise assessment are summarized below. The athlete's age, the symptoms described by the athlete, clinical signs and clinical suspicions should all be taken into consideration when deciding what tests to implement.

a) Stress test (ST) or ergometry:

The ST is used to evaluate the body's response to a metabolic overload. The ST is a fundamental tool for evaluating an athlete in two ways: the evaluation of their state of health, through the prevention and early diagnosis of cardiovascular disease, and, secondly, as a support for the training process.

There are specific guidelines for stress tests as applied to athletes, from a cardiological point of view (Rabadán, y Boraita, 2005; Manonellas Marqueta, Franco Bonforte, y Naranjo Orellana, 2016). These are:

- Evaluating the behavior of electrocardiographic changes during exercise that are typical in the athlete when observed at rest. This is used to check whether a first and second degree (Mobitz I) atrioventricular block (AVB), ectopic or wandering atrial rhythm or nodular escape rhythm resolves during exercise.
- Evaluation of professional athletes who are involved in high-risk or high intensity sports or in athletes over the age of 35, due to a higher prevalence of coronary artery disease in this age group (Borjesson et al., 2011).
- Evaluation of athletes with suspected heart disease: inverted T wave and ST segment depression, prolonged QT interval, ventricular preexcitation (serves to assess the risk of the accessory pathway), history of effort syncope, ventricular extrasystoles (if they disappear with exercise they are considered benign), first degree AVB greater than 400 ms, suspected exercise-induced tachyarrhythmias and in case of severe sinus bradycardia.
- Testing and monitoring athletes with diagnosed cardiopathy that does not initially impede physical exercise, as an indicator of aptitude for sports practice.
- Asymptomatic athletes under the age of 35 with a family history of exercise-related unexplained sudden death in first-degree relatives.

b) 24-hour Holter-ECG:

A Holter-ECG records heart rate and rhythm continuously over a period of 24 hours for further analysis. In the case of athletes, it is usually recommended that a training session be included in the 24-hour recording period, especially in the presence of symptoms during exercise, to increase the diagnostic usefulness of the test.

Guidelines for use in athletes:

- Recurrent syncope or syncope during exercise, mainly when a cardiogenic origin is suspected.
- To investigate frequent palpitations: suspected supraventricular tachyarrhythmia (paroxysmal supraventricular tachycardia, fibrillation and atrial flutter) and ventricular tachyarrhythmias.

- To investigate rhythm abnormalities in the basal ECG: presence of first degree AVB greater than 400ms, presence of second degree AVB (Mobitz I and II), third degree AVB, two or more ventricular extrasystoles in the basal ECG or presence of ventricular extrasystoles during ST, prolonged QTc interval, ventricular preexcitation, type I Brugada syndrome and marked sinus bradycardia (30 bpm).

- Assess the presence of arrhythmias if cardiomyopathy or myocarditis is suspected (Delise, Biffi, Giada, Gulizia, & Inama, 2017).

c) Transthoracic echocardiography (TTE):

The TTE is part of an advanced cardiovascular assessment, which is reserved for cases in which, during the initial screening, clinical manifestations or exploratory findings suggestive of cardiovascular pathology have been detected. M-mode, two-dimensional, color and Doppler images provide important information on the structure and function of the myocardium, valves, large vessels, the origin of the coronary arteries and the pericardium. Therefore, the TTE is considered the best diagnostic test for detecting the main causes of sudden cardiac death in young athletes.

Guidelines for using the TTE with athletes:

- The use of the TTE is indicated in athletes competing at the international level or federated athletes who are under the age of 35 with a family history of sudden death in a first-degree relatives (Boraita et al., 2000).

- Athletes with a family history of hereditary heart diseases such as hypertrophic cardiomyopathy, arrhythmogenic cardiomyopathy, among others.

- To investigate unexplained syncope in the initial screening.

- To investigate and monitor athletes with suspicion or diagnosis of pericarditis or myocarditis.

- Findings considered abnormal in the basal ECG, because of their usefulness for ruling out an underlying structural pathology, especially T wave inversion, ST segment depression, the presence of pathological Q waves, nonspecific severe intraventricular conduction disorder and left bundle branch block.

- Periodic assessment of non-disqualifying cardiac anomalies, such as a normally functioning bicuspid aortic valve without significant dilation of the ascending aorta, mild valvular disease or small left-to-right shunts.

- Screening and monitoring cardiovascular malformations associated with Marfan syndrome, especially for measuring different aortic diameters.
- It is worth mentioning the usefulness of stress echocardiography in evaluating changes in the ST segment and the T wave in the resting ECG, when there is suspicion of coronary anomalies or coronary artery disease, depending on the athlete's age (Franklin et al., 1997).

d) Cardiac magnetic resonance (CMR):

CMR is a highly accurate, reproducible technique that provides a more accurate measurement of cardiac morphology, overcoming some of the limitations associated with echocardiography. Furthermore, CMR is considered the technique of choice for a morphological and functional assessment of the right ventricle, in addition to its exclusive ability to detect myocardial fibrosis (Martinez, 2015, Prakken, Velthuis, Cramer & Mosterd, 2009).

Indications for use of CMR with athletes:

- Suspected hypertrophic cardiomyopathy, since CMR detects hypertrophy in the lateral and apical segments, and can more precisely measure parietal thicknesses.
- Suspected arrhythmogenic cardiomyopathy. CMR is the technique of choice to diagnosis this condition.
- Suspected dilated cardiomyopathy. CMR can better assess cavity volumes and the presence of intramyocardial fibrosis.
- In the event that myocarditis is diagnosed, to assess the extent of myocardial affection at the acute moment and the appearance of fibrosis upon follow-up.
- Suspected coronary artery disease. In this case, a stress CMR would be useful.

e) Computed tomography (CT) with athletes:

A CT scan of the coronary arteries is especially useful for suspected coronary artery disease, since it is a non-invasive angiographic assessment. In addition, a CT can precisely examine coronary anatomy and its epicardial trajectory, which is of special interest when there is suspected anomalies in the coronary arteries or intramyocardial bridges (Sperandi et al, 2017).

An aortic CT provides more precise information on aortic diameters, making it an especially useful technique in cases of aortic dilatation.

f) Other diagnostic tools for cardiological assessment of athletes:

Nuclear cardiac imaging is not recommended as a first-line test for competitive athletes. SPECT-MIBI detects alterations of perfusion in areas with left ventricular hypertrophy in healthy athlete hearts, which are therefore considered to be false positives (Bortram, Toft, & Hanel, 1998). Positron emission tomography has only been used in research studies.

Cardiac adaptation to training: physiological cardiac remodeling and potential pathological remodeling

Sports training induces a series of structural and electrical adaptations in the heart that have been classically referred to as the *athlete's heart* (Stout, 2008). This functional and structural cardiac remodeling is directly related to the type, duration and intensity of training. In this way, endurance sports that require increased oxygen consumption over long periods of time cause more marked electrical and structural changes to the heart (Pellicia, Culasso, Di Paolo, & Maron, 1999). Nevertheless, when clinically examining this cardiac adaptation to exercise, we must remember the influence of individual factors such as race, gender and genetics.

Exercise-induced left ventricular (LV) remodeling is characterized by an increase in the size of the cavity and a slight enlargement of ventricular wall thickness (Pellicia et al., 1999, Utomi et al., 2014). For black athletes or athletes with high strength training loads, this thickening of the myocardium may be more marked, exceeding the physiological limit of 13 mm and simulating hypertrophic cardiomyopathy. An increase in myocardial thickness will be accompanied by an increase in the ventricular cavity. Thus, a left ventricular end-diastolic diameter (LVEDD) greater than 54 mm or a relationship between the volume and mass of this augmented ventricle would be suggestive of physiological remodeling. On the other hand, hypertrophic cardiomyopathy reduces diastolic function (slows down relaxation) of the LV, whereas in an athlete this is normal or even supranormal (Caselli et al., 2014). For more information, see Table 1.

As noted above, LV dilation is common in an athlete's heart, but such dilation rarely exceeds normal limits (Pellicia et al., 2002). However, in athlete populations with high endurance training loads, extreme LV remodeling characterized by marked ventricular dilation (exceeding 60 mm) and systolic (contraction) function at the lower limit of normal has been noted in 45-50% of sampled populations (Abergel et al., 2004). These

alterations require that a differential diagnosis be performed with dilated cardiomyopathy. Also, as part of this process of the heart adapting to exercise, there may be an increase in the degree of trabeculation of both ventricles, which in selected cases can simulate non-compacted cardiomyopathy (Gatti et al., 2013). The ultimate goal of all the structural and functional changes of the heart in response to training is to improve cardiac performance during exercise. Thus, for a differential diagnosis between the physiological remodeling of the LV and the cardiomyopathies presented above, it is essential to evaluate the functional response of said ventricle to training, which we would expect to be preserved or increased (Gatti et al., 2013).

Traditionally, research on athlete hearts has focused on the LV. In the last decade, advances in cardiac imaging techniques have opened the door to better understanding of how the right ventricle (RV) and atria respond to exercise. At rest, these cardiac cavities work with low intracavitary pressures, which increase dramatically during exercise and make these cavities more vulnerable to increased myocardial wall stress experienced during exercise (La Gerche et al., 2011). In fact, in a small percentage of athletes, high endurance training loads have been related to extreme remodeling of the RV characterized by marked dilation, with a slight reduction in contractile function and a higher incidence of ventricular arrhythmias (Heidbüchel et al., 2003). All of these changes require a differential diagnosis to identify true arrhythmogenic RV cardiomyopathy (ARVC) along with potentially adverse exercise-induced remodeling of the RV. The echocardiographic parameters that would guide us towards physiological remodeling are: an increase in the contractile function of the RV in response to exercise and the harmonic dilation of all the cardiac cavities with a LV/RV ratio greater than 1 (Bauce et al., 2010). On the other hand, selective dilation of the RV outflow tract and the presence of alterations in the segmental contractility of this ventricle would lead us to consider ARVC (Bauce et al., 2010). Refer to Table 1 for a summary.

Endurance exercise has also been related to an increased likelihood of developing atrial fibrillation (Calvo et al., 2016). The underlying pathophysiological mechanisms are not yet clear, but pathological remodeling seems to play a key role. The echocardiographic parameters that would indicate potential atrial pathological remodeling are: severe dilation of the atrial cavity and an inability to increase its contractile and reservoir function during exercise (Sanz de la Garza et al., 2016; Gabrielli et al., 2016).

Table 1: Echocardiographic parameters for differential diagnosis between athlete's heart and the most prevalent cardiomyopathies

	Hypertrophic cardiomyopathy	Athlete's heart
Left ventricle end-diastolic diameter	← 45mm	> 54mm
LV volume/mass ratio	Reduced	Normal
LV diastolic function	Reduced	Normal or supranormal
	Dilated cardiomyopathy	Athlete's heart
LV resting contractile function	Reduced	Normal or mildly reduced
Increased LV contractile function with exercise	Decreased	Normal or supranormal
	Non-compacted cardiomyopathy	Athlete's heart
Location of trabeculation	Apical	Middle
Increased LV contractile function with exercise	Decreased	Normal or supranormal
	RV arrhythmogenic cardiomyopathy	Athlete's heart
RV dilatation	Predominant outflow tract	Global
	Yes	No

Segmental alterations	motility	
LV/RV volume ratio	→ 1	< 1
Increased RV contractile function with exercise	Decreased	Normal or supranormal

Source: Sanz de la Garza et al., 2016; Gabrielli et al., 2016

Cardiac pathology and sports

There are three main groups of cardiopathies that can be detected in the pre-participation screening: cardiomyopathies (Table 1); valvulopathies and aorta pathologies (Table 2); arrhythmias and channelopathies (Table 3). Specific congenital cardiopathies are not discussed in this unit, as advice regarding physical activity in these cases is provided by specialized hospital units. For each cardiopathy, there is a recommended level of exercise intensity, according to the type of recreational or competitive sport, as denoted in the red and yellow columns. However, the decision must always be individualized and personalized, taking into account the following three factors: a) severity of the cardiopathy; b) athlete comorbidities; c) modality (recreational or competitive) and type of sport.

Key for tables 1 and 2:

Y. **yellow:** Mitchell 1A competitive sports; recreational sports: low-moderate static component and intensity < 75% maximum HR or < 6 on the Borg scale.

R. **red:** competitive sports are contraindicated; recreational sport: low static component and intensity < 60% maximum HR or < 5 on the Borg scale.

Abbreviations: LV, left ventricle; EF, ejection fraction; DD, diastolic diameter; RV, right ventricle; PASP, pulmonary arterial systolic pressure.

Table 1: Recommendations for cardiomyopathy

Cardiomyopathies	Yellow (Y)	Red (R)
LV hypertrophy	SIV or PPD 13-15 mm	SIV or PPD > 15 mm or diagnosis of hypertrophic cardiomyopathy
LV function	LVEF 30-50%	LVEF < 30%
Coronary heart disease	If there is a risk criterion*	
ARVC	Asymptomatic [^]	Symptoms
Myocarditis-Pericarditis		Contraindicated acute phase [°]

Recommendations for cardiomyopathies. *Coronary disease risk criteria: 1) LVEF <50%, 2) symptoms, 3) ventricular ischemia or arrhythmia in the stress test, 4) significant coronary artery stenosis, 5) percutaneous or incomplete surgical revascularization. °Can perform physical activity after they normalize: laboratory markers, ECG, Echocardiogram (LVEF > 55% and absence of pericardial effusion), Holter (without arrhythmia). ^Symptoms: pre-syncope, syncope, resuscitated sudden death, malignant ventricular arrhythmia in 24-hour Holter or stress test.

Table 2: Recommendations for aortic and valvular diseases

Aortic and valvular diseases	Yellow (Y)	Red (R)
Aortic or pulmonary stenosis	Mild-moderate: maximum flow rate 2.6-4.0 m/s	Moderate-severe: maximum flow rate > 4.0 m/s Surgical assessment.
Mitral stenosis	Mitral area 1.0-1.5 cm ² and maximum effort PASP < 50 mmHg	Mitral area <1.0 cm ² or maximum effort PASP > 50 mmHg. Surgical assessment.
Mitral or aortic insufficiency	Moderate/severe insufficiency, DDLV < 63 mm and LVEF > 55%	Moderate/severe insufficiency, DDLV > 63 mm or LVEF < 55%. Surgical assessment.
Bicuspid aortic valve. Normally functioning: all sports.	Mild-moderate regurgitation or stenosis	Moderate-severe regurgitation or stenosis. Surgical assessment.
Mitral valve prolapse	If there is any risk criteria#.	
Dilated aortic root	40-45 mm	> 45 mm
Coarctation of the aorta	Z-score > 3, or arm-leg gradient > 20 mmHg, or hypertension effort	

"Recommendations for aortic and valvular diseases. #Criteria for mitral valve prolapse risk: syncope, ventricular arrhythmia, family history of sudden death, severe mitral insufficiency"

Table 3: Recommendations for arrhythmias and channelopathies

Arrhythmias and channelopathies	Yellow (Y)	Red (R)
Atrial fibrillation, atrial flutter. Anticoagulation, no impact sports.	HR controlled during exercise and no structural pathology	HR not-controlled during exercise or structural cardiopathy
Ventricular arrhythmia	VPB > 2000/24 hours and does not increase with exercise	VT not-sustained or VPB that increases with exercise
Sinus bradycardia, second degree AVB Mobitz I (Wenckebach)		HR < 30 bpm or pauses > 3 seconds, or block that does not normalize with exercise
Second degree (Mobitz II) or third degree AV Block	Asymptomatic [^] , no heart disease, block normalizes during exercise	Symptoms [^] or with base cardiopathy
Preexcitation syndrome or paroxysmic supraventricular tachycardia	Recreation: radiofrequency ablation: recommended	Competitive: radiofrequency ablation: indicated

ICD (implantable cardioverter defibrillator)	Only in sports with no impact risk.	
Brugada syndrome	Asymptomatic^	Symptoms^
Long or short QT syndrome	Asymptomatic^	Symptoms^
Catecholaminergic ventricular tachycardia	Asymptomatic^	Symptoms^

"Recommendations for arrhythmias and channelopathies. ^Symptoms: pre-syncope, syncope, resuscitated sudden death, malignant ventricular arrhythmia in 24-hour Holter or stress test"



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