Between the Physiological and the Pathological Spectra: When the Athlete's Heart Demands More Than Admiration

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The increasing participation in high-intensity sports has expanded the role of cardiology in athlete screening and monitoring. Although Sudden Cardiac Death (SCD) is rare, it has a deep impact on society as a whole. Echocardiography is central in this setting, serving as the primary imaging modality to distinguish physiological remodeling in the athlete's heart from structural cardiomyopathies.

Prolonged and intense exercise induces adaptive phenotypic and physiological changes that enhance myocardial performance. These adaptations, known as "athlete's heart," are extensively studied because they need to be differentiated from potentially fatal cardiovascular diseases.[1-3] The Athlete's Heart shares phenotypic characteristics with several pathological conditions, such as Hypertrophic Cardiomyopathy (HCM), Dilated Cardiomyopathy (DCM), and Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC).[4] Cardiologists need to be aware of these overlaps to correctly diagnose and prevent serious outcomes, especially in young, apparently healthy individuals, who may not experience symptoms until they engage in intense exercise. Equally important is the ability to identify normal adaptive cardiac remodeling, thereby enabling precise screening and appropriate guidance for elite athletes.

Pre-participation sports evaluation is recommended as a preventive measure for athletes' SCD and begins with clinical evaluation and electrocardiography. However, up to 16% of SCD cases are linked to structural heart disease without electrocardiographic abnormalities.[5] Many of these conditions could be detected earlier through cardiovascular imaging. For this reason, some professional sports organizations have incorporated echocardiography, a low-cost and widely accessible tool, into initial screening protocols, and in some cases, as the only test performed at baseline evaluation. [6, 7]

This editorial underscores the importance of identifying echocardiographic "red flags" in athletes, findings that may warrant further investigation or temporary restriction from competition. These borderline features, situated between physiological adaptation and early disease, demand both high-quality image acquisition and expert interpretation. Therefore, defining the scope of relevant echocardiographic parameters in this population, as well as clarifying when adaptations should raise suspicion of pathology, remains a key priority.

Keywords

Echocardiography; Exercise-Induced Cardiomegaly; Cardiomyopathies

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Comprehensive Echocardiographic Evaluation in Athletes

A well-conducted echocardiogram should follow minimum quality protocols and be tailored to the athlete's clinical context.[8] To increase sensitivity in detecting structural heart disease, it is recommended that athletes' echocardiograms include:

1. Multiple short-axis views to assess ventricular wall thickness in all segments.
2. Detailed assessment of the presence of myocardial trabeculations.
3. Visualization of the origin of the left and right coronary arteries.
4. Measurement of Left ventricular Global Longitudinal Strain (GLS) and Left Atrial Strain (LAS) whenever possible.

Echocardiography in Athletes: What is Expected?

Evaluating an athlete's heart requires not only technical expertise from the echocardiographer but also clinical sensitivity to recognize the complexities and nuances of physiological remodeling. Recognizing that there will often be uncertainties in the interpretation of the findings is important, which may require more specific and targeted additional investigations. To achieve this, the health professional must fully understand the expected cardiac adaptations, the variability of findings according to the type and volume of exercise, and the impact of factors such as the athlete's ethnicity, sex, age, and body composition.[8]

Structural and functional changes in the athlete's heart vary widely according to the predominant type of effort involved in the sport. Endurance sports, for example, tend to cause greater dilation of the cardiac chambers, while strength sports can lead to a more pronounced increase in ventricular wall thickness. Table 1 summarizes the main echocardiographic characteristics expected in the normally adapted athlete's heart.

Echocardiographic Red Flags: How to Recognize Suspicious Alterations in an Athlete's Heart

Certain echocardiographic findings should raise suspicion of pathology in athletes because they deviate from typical

physiological adaptations. A septal wall thickness > 15 mm or significant asymmetry points to possible HCM. Left Atrial dilation disproportionate to ventricular dilation indicates chronic overload or diastolic dysfunction. E/e' values greater than 14 suggest elevated ventricular filling pressure, which is unusual in normal adaptations. A reduction in GLS (< -16%) may reveal subclinical dysfunction even with preserved ejection fraction, while a LA reservoir strain measurement below 38% is an early sign of impaired atrial compliance. Furthermore, the presence of excessive trabeculations, apical aneurysms, or segmental dysfunction deviates from the physiological pattern. These criteria justify the need for further investigation.[2]

Table 2 summarizes the main echocardiographic red flags, their related entities, and the rationale for each to be considered a warning sign.

Table 1 – Normal echocardiographic findings in the athlete's heart[2]

Echocardiographic finding	Description in athletes
Cardiac chamber dilation	Symmetrical dilatation of LV and RV; common in several modalities.
Left ventricular thickening	Slight increase in wall thickness, especially in endurance athletes.
Eccentric LV remodeling	Increased LV volume without disproportionate thickness.
LV systolic function	Preserved or increased when assessed by specific methods, such as longitudinal strain by speckle tracking, this is evident even when the ejection fraction is slightly reduced.
Diastolic function	LV diastolic function is usually preserved or even optimized in adaptive states, as is the case with the "supernormal" pattern with a mitral inflow E/A ratio >2.
Atrial dilation	Frequent biatrial dilation, especially in men.
Aortic root	Slight dilation of the aortic root may occur within physiological limits.

AE: Átrio esquerdo; VD: Ventrículo direito; VE: ventrículo esquerdo.

Table 2 – Echocardiographic Red flags[2,4,8-10]

Red Flag Ecocardiográfica	Possível Entidade Associada	Justificativa Clínica
Septal thickness ≥ 15 mm or Septal thickness between 13–15 mm and associated with LVDD ≤ 53 mm, LA anteroposterior diameter ≤ 39 mm, diastolic dysfunction, concentric geometry, or hypertrophy asymmetry (IVS: PP ratio ≤ 1.3).	Hypertrophic cardiomyopathy	Values above physiological limits suggest structural pathology. Values that fall in the gray zone (13–15 mm) when associated with small chambers and/or asymmetry and/or diastolic dysfunction also suggest hypertrophic cardiomyopathy.
Isolated Left Ventricular Dilation	Dilated cardiomyopathy	Isolated left ventricular dilation should not be considered physiological and should raise immediate suspicion of dilated cardiomyopathy.
Disproportionate left atrial dilation or pronounced increase in LA anteroposterior diameter (men > 50 mm, women > 45 mm)	Hypertrophic Cardiomyopathy or Early Diastolic Dysfunction	Although it can occur in isolation, in physiological adaptive situations, it tends to coexist with ventricular enlargement, therefore, isolated or disproportionate LA enlargement should raise suspicion of a pathological cause.
E/e' > 14	Increased Ventricular Filling Pressure	Indicator of elevated filling pressure, an unusual condition in healthy athletes, and indicative of the presence of myocardial disease.
LVEF ≤ 47%	Dilated cardiomyopathy	There is indeed a decrease in resting LVEF in athletes (between 53-48%), but values below this range raise suspicion of cardiomyopathy.

GLS < -16%	Hypertrophic cardiomyopathy (if associated with LV hypertrophy) or subclinical LV dysfunction of any etiology	Early functional alteration, even with preserved ejection fraction. Adaptive LV hypertrophy does not reduce GLS.
RAS < 38%	Diastolic dysfunction or chronic overload	Early sign of loss of atrial compliance.
Excessive trabeculations + segmental dysfunction and/or myocardial wall thinning (end-diastolic thickness < 5 mm)	Non-compaction myocardium	Prominent trabeculations may occur in healthy athletes, but concomitant segmental dysfunction and/or myocardial wall thinning indicate a pathological origin.
Significant LV dilation + systolic dysfunction	Dilated cardiomyopathy	Combination incompatible with isolated physiological adaptation.
RV dilation* + contractile abnormalities or aneurysms (including in the LV)	Arrhythmogenic RV cardiomyopathy	Suggests RV structural involvement outside the athlete's spectrum.
Coronary artery origin anomalies	Malignant coronary artery course susceptible to ischemia	Abnormalities indicating an interarterial or intramural course are susceptible to coronary obstruction and, therefore, a risk of sudden death. Even non-classically malignant anomalies (retroaortic and prepulmonary courses) should indicate further evaluation.

** The presence of RV longitudinal dysfunction (S' ≤ 9 cm/s and/or TAPSE ≤ 16 mm) or reduced RV FAC (< 31%) is not normal in athletes and indicates further evaluation with stress echocardiography. LA: Left atrium; LVDD: Left ventricular diastolic diameter; LVEF: Left ventricular ejection fraction; PP: Posterior wall; GLS: Global longitudinal strain; IVS: Ventricular septum; RAS: Left atrial reservoir strain; RV: Right ventricle.*

How to Manage Suspicious Findings on Athletes' Echocardiograms?

The identification of a red flag on echocardiography should not, by itself, justify the athlete's immediate disqualification. Any isolated abnormality must be interpreted within a broader clinical context that considers symptoms, family history of sudden cardiac death or cardiovascular disease, electrocardiographic findings, and the nature of the sport involved. Within this integrated framework, the echocardiographer plays a pivotal role, not only in documenting structural or functional alterations but also in identifying patterns that warrant further investigation. This may call for additional testing, including three-dimensional echocardiography, cardiac magnetic resonance imaging, exercise stress testing, or genetic analysis.

Conclusion

Echocardiography remains the cornerstone for structural and functional evaluation of the athlete's heart. A clear understanding of its strengths and limitations, combined with the expertise of the echocardiographer, is essential to distinguish true warning signs from benign findings, safeguarding the athlete's health while avoiding unnecessary restriction from sports participation.

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