

My Approach to “Athlete’s Heart”: Evaluation of the Different Types of Adaptation to Exercise

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Abstract

Exercise-induced adaptation may occur in amateur and professional athletes. This condition is commonly named “athlete’s heart”. The alterations observed include dilation of the heart chambers, increased myocardial thickness, improved ventricular filling, increased left ventricular trabeculation, dilation of the inferior vena cava, among others. These changes can also be observed in some heart diseases, such as dilated, hypertrophic and other cardiomyopathies (CMP). Thus, cardiac imaging tests are fundamental in identifying these alterations and in differentiating between “athlete’s heart” and possible heart disease.

Introduction

Exercise-induced structural and/or functional heart alterations have been the object of study for more than 100 years, with their first reports appearing at the end of the nineteenth and the beginning of the twentieth century, referent to a dilated heart and a lower heart rate.¹ The development of complementary exams showed changes in electrocardiograms, chest X-rays, echocardiography, among other exams in athletes.¹

Exercise-induced cardiac remodelling depends on a wide range of variables, including the type of exercise, the intensity, and the duration of training, generally with a “dose-effect” relation.² It is interesting to note that other variables are also involved in the adaptation, such as age, ethnicity, gender, and body size.²

The growing number of amateur and professional athletes periodically submitted to a cardiological evaluation before participating in activities or during the years of sports practice has led to a challenge in recognizing exercise-induced adaptation and its difference from potentially fatal heart conditions, such as hypertrophic cardiomyopathy (CMP), dilated CMP, arrhythmogenic right ventricular CMP, and non-compacted myocardium.¹

Keywords

Athlete’s heart; ecocardiography; cardiomyopathy; adaptive cardiac remodeling

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Types of exercise

Sports activities can be divided, in a simplified manner, into four categories: skill, power, endurance, and mixed. These activities mix, in greater or lesser quantity, isotonic (dynamic) and isometric (static) exercises, according to that described in Chart 1:²

In this sense, the type of exercise will result in the exercise-induced cardiac remodelling observed in these individuals’ imaging exams. Thus, the greater the load of isotonic exercise, the greater the volume overload and the greater the possibility of observing a dilation in the heart chambers. By contrast, the greater the pressure overload, the greater the possibility of finding a dilation in the myocardial thickness.²

It is also important to observe that no type of sport is purely isotonic or isometric. Therefore, physical activities can present a greater or lesser predominance of one type of exercise, such as that mentioned above.² The classification adapted from the European Association of Cardiovascular Imaging and from the European Association of Preventive Cardiology is presented below, which shows the quantity of isometric and isotonic exercise associated with the main sports, as well as the intensity of the cardiac remodelling to them (Chart 2).²

Thus, it is possible to predict the exercise-induced cardiac remodelling that can be observed in the imaging exams³ (Chart 3).

Other adaptations are observed with sports practice⁴⁻⁶ (Chart 4).

Intensity and prevalence of exercise-induced cardiac remodelling

Though explained well in the literature and with a consensus regarding the exercise-induced cardiac remodelling described in this text, it is important to emphasize that not all of the athletes present these adaptations in imaging exams.^{2,7,8}

For example, many studies conducted to evaluate the different ethnicities and modalities have shown the following

Chart 1 – Types of exercise and their alterations in cardiovascular physiology²

Type of exercise	Characteristic	Cardiac output	Peripheral vascular resistance	Result
Isotonic	Dynamic	Significant increase	Decrease	Volume overload
Isometric	Static	Slight increase	Increase	Pressure overload

Chart 2 – Characteristics of the exercises of different sports and intensity of the cardiac remodelling²

	Skill	Power	Endurance	Mixed
Isotonic	+/-	+ / ++	+++ / ++++	++ / +++
Isometric	+/-	+++ / ++++	++ / +++	++ / +++
Cardiac remodelling	+/-	+ / ++	++++	++ / +++
Sports	Table tennis, Karate, Golf, Yachting, Equestrianism	Weight lifting, Judo, Boxing, Short-distance running. Discus/Javelin throw, Olympic Gymnastics, Short-distance skating	Medium/Long-distance running, Medium/Long-distance cycling, Medium/Long-distance swimming, Triathlon, Canoeing/Rowing, Long-distance skating	Soccer, Volleyball, Basketball, Tennis, Handball, Rugby, Water polo, Fencing

prevalence of left ventricular myocardial thickness ≥ 12 mm² (Chart 5).

One study evaluating elite athletes showed that 48% of them present a left ventricular diastolic diameter (LVDD) of above 55 mm, while only 14% present a LVDD ≥ 60 mm. The average LVDD among women was 48.4 ± 4.2 mm (varying from 38 to 66 mm), whereas among men the average was 55.4 ± 4.3 mm (varying from 43 to 70 mm). There was a correlation between the LVDD and the body surface area ($r = 0.76$; $p < 0.001$).⁷ Figure 1 demonstrates an example of dilation of the left atrium and left ventricle in an amateur street race athlete.

It is important to highlight that in one study published by Caselli et al. in 2015 in the Journal of the American Society of Echocardiography, the left ventricular ejection fraction (LVEF) was normal throughout the studied population (1,145 Olympic athletes), with the lower limit for LVEF being 53%.⁸

This same study also showed that the left atrial diameter was larger than that of non-athletes; however, no differences were found when the diameter was indexed for the body surface area. Among athletes, 10% presented an LA diameter of above the reference values. In addition, 5.5% of the athletes presented an LVDD of above 60 mm and only 2.6% showed a myocardial thickness ≥ 13 mm.⁸

In children and adolescent athletes, one can also observe a dilation in the LA and LV, and a slight increase in the myocardial thickness.⁹

Differentiation between the exercise-induced adaptation and heart diseases

Some echocardiographic tools, such as the Tissue Doppler (TD) and cardiac magnetic resonance (CMR) aid in the differentiation between the “athlete’s heart” and heart diseases.^{10,11}

The exercise-induced alterations do not reduce the speed of the wave e' or increase the E/e' ratio.⁴

Another important point, and which can aid in determining the differentiation in relation to heart diseases, is the absence of a decrease in myocardial deformation (Strain values) in the “athlete’s heart”, observing negative values of higher than -18%.¹⁰

Chart 3 – Cardiac remodelling according to the characteristic of the exercise³

	Isotonic (dynamic) Exercise	Isometric (static) Exercise
LV	Dilation	Minimum alteration in volume and without dilation
LV myocardial thickness	No alteration or minimal alteration	Increase
LV geometry	Excentric hypertrophy	Concentric hypertrophy
LA	Dilation	Dilation and/or hypertrophy
RV	Dilation	No alteration
RA	Dilation	No alteration

RV: right ventricle; LV: left ventricle; LA: left atrium; RA: right atrium.

Chart 4 – Adaptations observed with sports practice.⁴⁻⁶

Structure	Adaptation
Improved left ventricular filling	Wave $e' > 9$ cm/s $E/e' \text{ Ratio} < 6$
Inferior vena cava	Dilation
Myocardial trabecular	Prominent trabeculations Increase in trabecular volume

Chart 5 – Prevalence of LV myocardial thickness ≥ 12 mm² according to ethnicity

Ethnicity	Prevalence
Blacks	18%
Caucasians	2%
Asians	2%
Arabs	< 1%

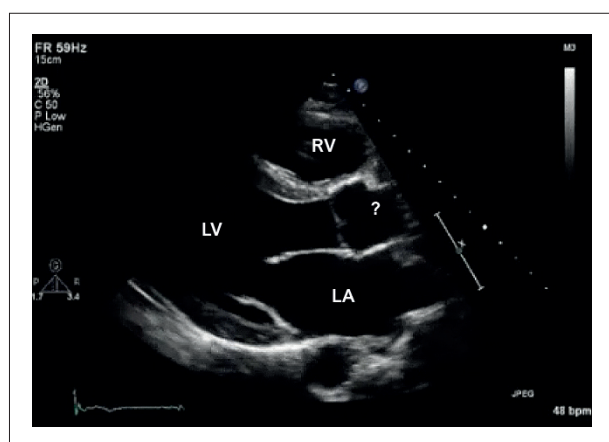


Figure 1 – Longitudinal parasternal cut in an echocardiography exam of a 36-year-old man, amateur athlete in marathons (10 K, half-marathons, and marathons). We observed an increase in the diameter of the left atrium (LA) (45 mm) and the diastolic diameter of the left ventricle (LV) (60 mm). RV: right ventricle; LV: left ventricle; LA: left atrium; AO: aorta.

In questionable cases, the CMR is also very important in the differentiation between the athlete's heart and heart diseases, given that, in the athlete's heart, there is no delayed enhancement, no hypersignal in T1, or myocardial fat (this final concept in the differentiation from right ventricular arrhythmogenic CMP).¹¹

According to the characteristics observed in each "athlete's heart", the diagnostic differentiation should be performed with hypertrophic CMP, dilated CMP, arrhythmogenic right ventricular CMP, and/or non-compacted myocardium. In some specific cases, this differentiation can be more challenging, since it can exist in a "grey area" with similar characteristics among the different heart diseases and the exercise-induced adaptations (Figure 2).^{2,4}

Below are some points that aid in the differentiation in relation to each of the following heart diseases^{2,4,11} (Chart 6).

Conclusion

The regular and intense practice of physical activity can induce a wide range of cardiovascular adaptations, including electric, structural, and functional adaptations. These exercise-induced adaptations can often coincide with alterations observed in some heart diseases. Cardiac imaging plays a key role in the differentiation between the "athlete's heart" and pathological cardiovascular alterations, particularly in structural and functional evaluations.

Author Contributions

Conception and design of the research, acquisition of data, analysis and interpretation of the data, statistical analysis, obtaining financing, writing of the manuscript, critical revision of the manuscript for intellectual content: Mancuso FJN.

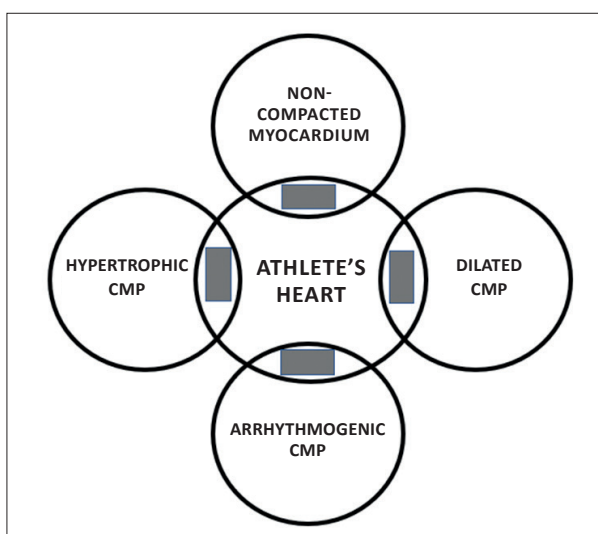


Figure 2 – "Grey area" of the overlapping between the "athlete's heart" and some heart diseases (CMP).² CMP: cardiomyopathy.

Chart 6 – Elements that help in the differentiation between adaptation to exercise and cardiomyopathies^{2,4,11}

Dilated myocardial thickness (13 to 16 mm) – Findings that suggest hypertrophic CMP

- Normal or reduced LVDD (< 54 mm)
- Segmental hypertrophy of the LV
- Obstruction of the left ventricular outflow tract
- Alteration of the diastolic function (wave e' < 8.0 cm/s and/or E/A relation < 1.0)
- Left atrial dilation disproportional to the left ventricular dilation
- Delayed enhancement in the CMR

Heart chamber dilation – Findings that suggest dilated CMP

- Left ventricular dilation disproportional to the other heart chambers
- Left ventricular diastolic dysfunction
- Alteration in segmental contractility
- Reduced systolic volume
- Delayed enhancement in the CMR

Prominent Trabeculation in the LV – Findings that suggest non-compacted myocardium

- Left ventricular dilation disproportional to the other heart chambers
- Left ventricular systolic dysfunction
- Trabeculation associated with the thinning of the myocardial wall
- Delayed enhancement in the CMR

Heart chamber dilation – Findings that suggest arrhythmogenic right ventricular CMP

- Right ventricular dilation disproportional to the other heart chambers
- Alteration in segmental contractility of the right and/or LV
- Delayed enhancement in the right and/or LV in the CMR

CMP: cardiomyopathy; LV: left ventricle; LVDD: left ventricular diastolic diameter; CMR: cardiac magnetic resonance.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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