

[Primary Care]

Cardiovascular Health, Part 1: Preparticipation Cardiovascular Screening

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Context: Identification of potentially fatal cardiac conditions in otherwise healthy athletes presents a major challenge to the sports medicine community. The requirements for preparticipation screening vary among countries and even from state to state within the United States. The mandated use of an electrocardiogram as a screening implement has provoked international controversy.

Evidence acquisition: Part 1 of this review highlights the current guidelines and controversies surrounding cardiovascular screening, with a focus on the diagnostic challenges associated with identifying athletes with inheritable cardiomyopathies. Data sources were limited to peer-reviewed publications from 1984 to the present.

Results: Preparticipation screening should include at least a history and a physical examination for all athletes, whereas use of an electrocardiogram is still controversial. Diagnosis of inherited cardiomyopathies presents unique challenges, particularly in hypertrophic cardiomyopathy, where many features can mimic those found in the “athlete’s heart.”

Conclusions: Recognizing cardiac conditions in athletes that can predispose them to sudden cardiac death or other adverse outcomes is of vital importance, as is the appropriate exclusion of these athletes from competition. Further studies are needed to determine the most efficient and cost-effective means of screening and to increase the sensitivity and specificity of diagnostic testing for inheritable cardiovascular diseases.

Keywords: athletes; cardiovascular screening; cardiomyopathies; athlete’s heart

When an athlete presents with chest pain, palpitations, or other cardiac symptoms, it is a tremendous source of concern for any health care professional or athletic trainer. This concern stems from the possibility of devastating injury or sudden death, as well as the lack of data or expert consensus regarding not only the appropriate evaluation and care of athletes with cardiac conditions but also the return-to-play criteria. Although these conditions are fortunately very rare, sudden deaths and other potentially life-threatening events in high-profile athletes have resonated in the collective psyche of athletes, their families, and sports medicine providers. Part 1 of this review synthesizes the current recommendations and highlights the controversies regarding the preparticipation screening of all athletes. It also discusses the diagnostic dilemmas and risks associated with sports participation of athletes with inherited cardiomyopathies.

THE SCOPE OF THE PROBLEM

There are approximately 10 to 12 million young athletes in this country. These young athletes compete at all levels, ranging from middle school physical education class to the competitive collegiate level.²⁶ The majority of these athletes are completely healthy and cardiac conditions are extremely rare. The challenge arises from trying to identify clinically silent but potentially devastating conditions in this population in an efficient and economical manner. Furthermore, many athletes will minimize or fail to report symptoms—that is, until they become unmanageable—for fear of negative repercussion from coaches and/or family members. Therefore, it is vital for all sports medicine providers to educate athletes about the need for immediate and truthful reporting of cardiac symptoms.

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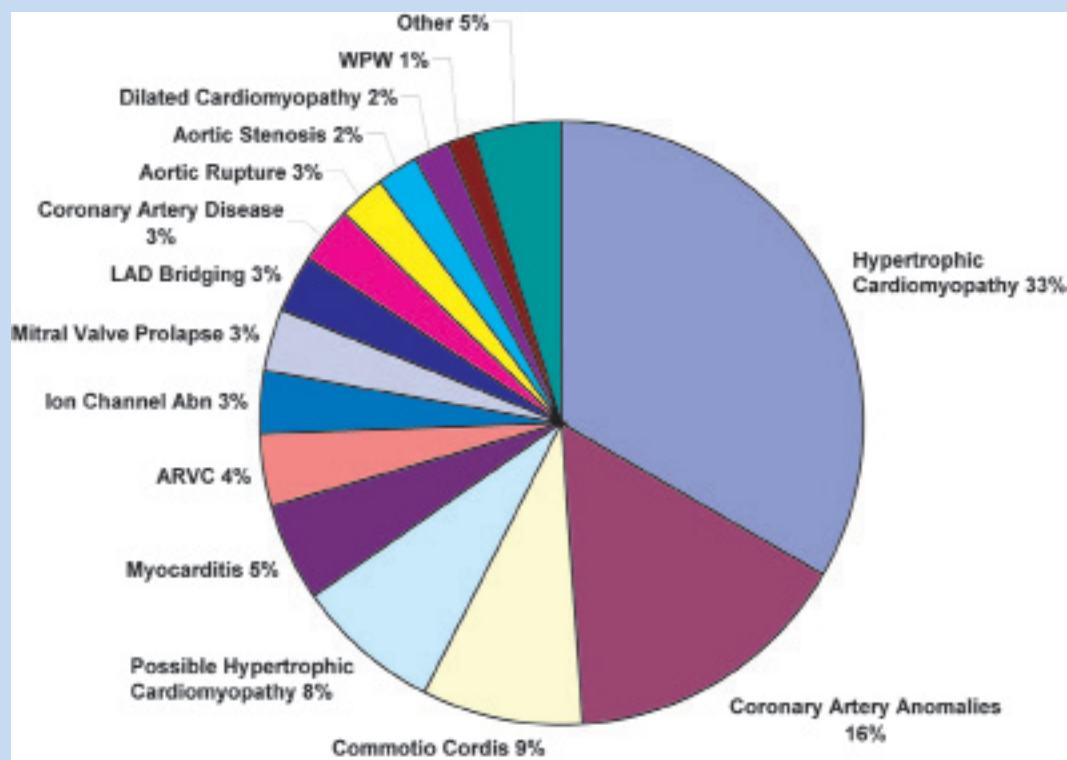


Figure 1. Cardiovascular causes of sudden death in young athletes (age < 40 years; n, 755). WPW, Wolff-Parkinson-White syndrome; LAD, left anterior descending; ARVC, arrhythmogenic right ventricular cardiomyopathy. Adapted from Maron et al.²⁵

Risk of Sudden Cardiac Death in Athletes

The rationale for restricting athletic activity in individuals with various forms of heart disease is largely based on an increased risk of sudden cardiac death (SCD) in trained athletes, compared to nonathletes, in population studies. In one Italian study, the relative risk of cardiovascular SCD in athletes aged 12 to 35 years was 2.5 compared to nonathletes.¹⁰ The overall annual rate of SCD in US athletes is 1 in 50 000 to 200 000.²⁴ Recent data confirm previous findings that the most common cause of SCD in athletes is hypertrophic cardiomyopathy (HCM), followed by coronary artery anomalies and commotio cordis (Figure 1).²⁵ SCD in athletes most often occurs during or shortly after intense training or competition.^{24,28} The acute physiological, emotional, and psychological effects, along with often extreme or unpredictable environmental conditions, contribute to the risk of triggering a life-threatening arrhythmia. For reasons that are unclear, published observations on SCD in athletes show a male predominance (> 90%), a disproportionate number of HCM-related SCDs in black versus white athletes (20% versus 10% with respect to total number of athletes with HCM), and a much higher incidence of SCD in certain sports, such as basketball and football.^{25,28,46}

Preparticipation Screening

Health care professionals and athletic trainers typically conduct preparticipation screening on all participants of a particular sport

before the start of training camp. For large high schools and colleges, the sheer number of athletes who require screening requires a tremendous amount of coordination among medical staff to conduct such examinations efficiently and effectively. For the cardiovascular portion of the examination it is important for the following to be included.

Personnel. When possible, physicians should perform the cardiac portion of the exam. Internists, pediatricians, family practitioners, and cardiologists all have experience in cardiac auscultation and should be comfortable with the interpretation of diagnostic tests. If a physician is not available, the sports medical staff should identify one for the referral of any athletes who have concerning elements on their screening questionnaires or preparticipation examinations.

Screening questionnaire. Five national medical/sports organizations have created a monograph that describes a standardized form of the preparticipation examination, which includes a screening questionnaire, a urinalysis, a limited physical examination, and a sports clearance statement for the physician to sign.³ However, there is tremendous variability in the means by which the preparticipation examination is implemented from state to state and, in some cases, between schools within the same state. There is often no state requirement to perform a preparticipation examination for middle school intramural participants, despite the fact that

physical education is required for all students in grades K-12. At a minimum, the following questions should be included in the preparticipation questionnaire²⁶:

- Is there a family history of heart disease (heart attack, heart bypass surgery, stent placement, etc) in a surviving relative under the age of 50?
- Has there been a family member that was under the age of 40 that died suddenly and unexpectedly?
- Have you ever been told by a doctor that you have a heart murmur or high blood pressure?
- Do you ever have chest pain while you exercise?
- Have you ever passed out during or after exercise?
- Have you ever had excessive or unexplained shortness of breath while exercising?
- Have you had persistent fatigue, out of proportion to your level of activity, that prevented you from participating in the same activities as your peers?

Physical examination. The cardiac portion of the physical examination should be conducted in a quiet room by a qualified health care professional. A calibrated cuff should be used to measure blood pressure, and heart rate should be checked by manual palpation of the radial or carotid pulse for 30 seconds. Ideally, blood pressure measurement should be performed with the arm held at the level of the heart and with the athlete having been seated at rest for at least 5 minutes.⁴³ Cardiac auscultation should be performed with the athlete in a recumbent and standing position, in aortic and pulmonic valve areas (right and left of sternum in second intercostal space), the tricuspid position (fourth intercostal space at left of sternum), and apex position (fifth intercostal space in midclavicular line). Auscultation should be repeated while having the athlete perform a Valsalva maneuver, such as taking a deep breath and holding it or tightening abdominal muscles and “bearing down.” This maneuver will help to elicit any subclinical valvular heart disease or outflow tract obstruction suggestive of HCM.

The Electrocardiogram Controversy

The primary objective of the cardiac portion of the preparticipation examination is to identify athletes at risk for SCD. The challenge arises in that more than 12 million athletes need to be screened annually although the estimated prevalence of cardiac conditions that lead to SCD is only 0.3%.²⁴ Unfortunately, the preparticipation history and physical examination lacks adequate sensitivity for the identification of athletes at risk for SCD. In a retrospective study, only 3% of trained athletes who died suddenly from cardiovascular disease were identified as having an abnormal preparticipation examination, and none were disqualified from competition.²⁸ These results stand in contrast to the experience in Italy, where it is mandatory for all athletes to be tested annually with a history and physical examination as well as an electrocardiogram (ECG). This program, implemented via a

national law in 1982, screens Italian citizens of all ages who are participating in official competitive sports activities. The Italians have witnessed an 89% decrease in SCD in athletes since this program was implemented.^{9,38} Specifically, they observed a decrease from 3.6 SCDs per 100 000 patient-years in 1979-1980 (before program implementation) to 0.4 SCDs per 100 000 patient-years in 2003-2004.⁹ Influenced by these results, the European Society of Cardiology and the International Olympic Committee have recommended the inclusion of a 12-lead ECG into the preparticipation examination for all competitive athletes. However, the American Heart Association and the American College of Cardiology have not adopted this recommendation. One of their presenting arguments is that the overall rate of death after the Italian intervention was comparable to the current mortality rate in the United States. A detailed discussion regarding the controversy of including a 12-lead ECG as part of preparticipation athlete screening is beyond the scope of the current review but has been highlighted in a number of recent articles.^{8,11,15,30,33,41}

In short, the controversy centers on financial, ethical, and logistic considerations of a national or international mandate to include an ECG as part of the screening process. Many athletic programs lack the resources to purchase equipment and/or hire personnel to perform and interpret athletes' ECGs. Unlike in Italy, where the cost of screening is supported by the National Health System, national resources for the comprehensive screening of all athletes in the United States and many other countries do not presently exist. The ethical concerns arise from the fact that up to 30% to 40% of elite athletes have abnormalities on their ECG that may mimic cardiovascular disease and that these abnormalities are more prevalent in African American athletes.²¹ The majority of these findings will turn out to be manifestations of the “athlete’s heart.” However, the burden of undergoing further medical workup, the inability to compete until the issue is resolved, and the emotional toll upon the athletes and their families during this time of uncertainty are all issues that merit consideration. Finally, the logistics of implementing a national program of screening ECGs for all eligible athletes are challenging, given that preparticipation screening examination standards differ between high school and college, as well as from state to state.

INHERITED CARDIOVASCULAR DISEASES AND ASSOCIATED RISKS FOR SPORTS PARTICIPATION

One of the biggest concerns pertaining to athlete screening is the accurate detection of inheritable cardiovascular diseases that together account for the largest proportion of sudden deaths during sports participation in young athletes. Diagnosis of inherited cardiomyopathies can be particularly challenging, given that many electrocardiographic and structural manifestations can mimic those found in the athlete’s heart. The following section focuses on the diagnosis and management of these cardiomyopathies and their associated risks for sports participation.

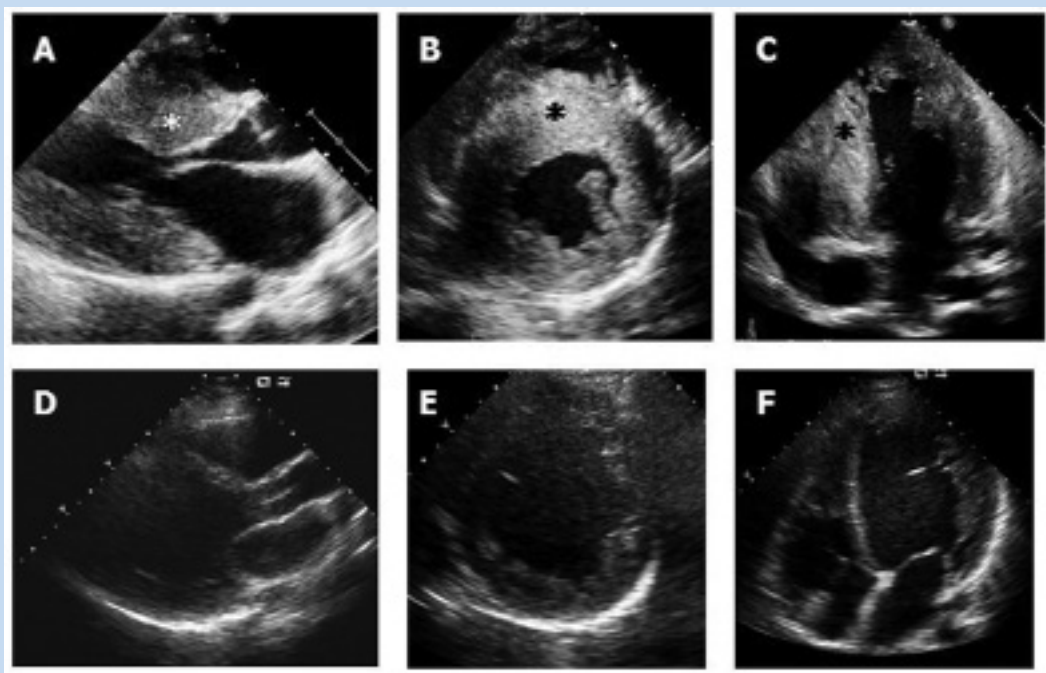


Figure 2. Echocardiographic images of hypertrophic and dilated cardiomyopathies. A-C, parasternal long-axis, short-axis, and 4-chamber echocardiographic views of a patient with hypertrophic cardiomyopathy and severe hypertrophy. The hypertrophy is concentric but most pronounced in the intraventricular septum, as denoted by an asterisk (*), which measures 37 mm. D-F, parasternal long-axis, short-axis, and 4-chamber echocardiographic views of a patient with dilated cardiomyopathy.

HCM and Other Cardiomyopathies

HCM is the most common inherited heart muscle disorder, with a prevalence of 1 in 500, independent of race, gender, or geographical location.²³ It is characterized by wall thickening in any distribution of at least 13 mm in the absence of any hemodynamic stimulus (such as hypertension or aortic stenosis) sufficient to account for the degree of hypertrophy. The ventricular chamber is typically of normal or small size, and the systolic function is usually normal or greater than normal. The degree and pattern of hypertrophy vary, but the most well-recognized variant is asymmetric hypertrophy of the intraventricular septum often associated with systolic anterior motion of the mitral valve and left ventricular outflow tract obstruction (Figures 2A-2C and 3A-3C).^{23,32,34} The age at diagnosis and long-term prognosis are highly variable. Whereas approximately 25% of patients with HCM have normal longevity free of significant cardiovascular symptoms, a subset of patients experience symptoms of exercise intolerance and congestive heart failure, which in some cases necessitate surgical intervention or cardiac transplantation.¹⁶ Relevant to the field of sport cardiology is the risk of SCD related to HCM, which averages about 1% per year overall.¹⁶ Risk stratification algorithms identify those at high risk who should be considered

for implantable cardioverter-defibrillator placement.^{17,29} HCM is the most common cause of SCD in young athletes (< 35 years) in the United States, accounting for about 1/3 of the deaths in this population.²⁴ Importantly, this risk is independent of other risk factors for SCD. Clinical diagnosis is conventionally made with 2-dimensional echocardiography, but cardiac magnetic resonance imaging (MRI) has emerged as a valuable diagnostic tool and may be useful in the athletic population for differentiating HCM from athlete's heart.^{35,42} HCM is caused by a variety of mutations in genes, most of which encode for proteins of the cardiac sarcomere, or contractile apparatus.^{2,45,51} Clinical genetic testing can aid in diagnosis and be used for preclinical screening of family members.

Dilated cardiomyopathy (DCM) has an estimated prevalence of 1 in 2500; it is characterized by ventricular chamber enlargement and systolic dysfunction³¹ (Figures 2D-2F, 3D). Approximately 35% of DCM patients are believed to have an inherited form.² The remaining cases are due to infectious, toxic, autoimmune, or other systemic disorders. Myocarditis is an acute inflammatory process that may partially or completely resolve but may also progress to DCM. Although the prognosis is variable, DCM more often results in congestive heart failure and the need for cardiac transplantation, when compared to HCM. The risk of SCD correlates with disease severity and degree of left ventricle

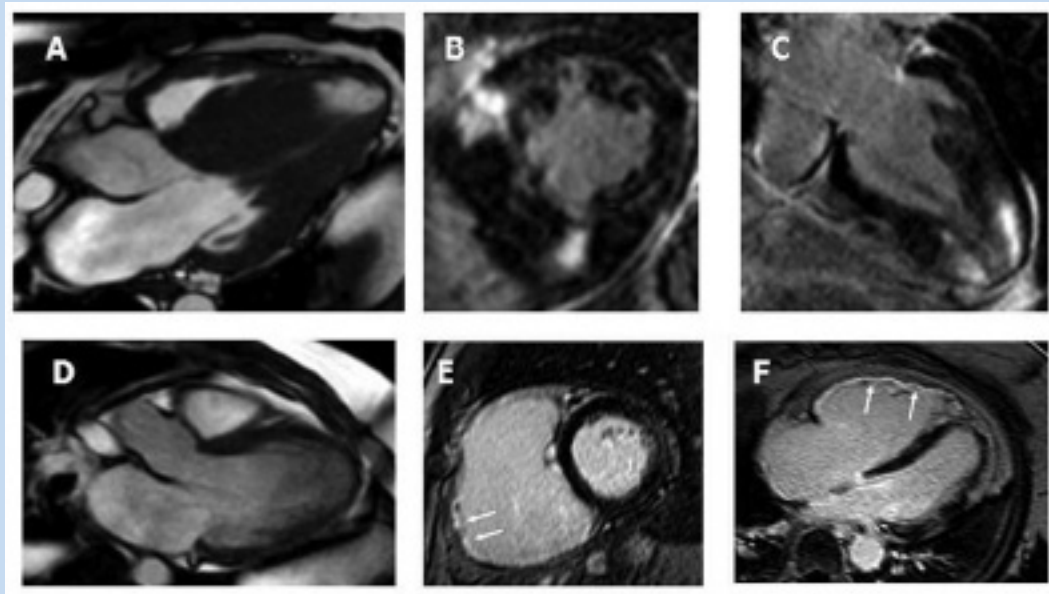


Figure 3. MRI of hypertrophic, dilated, and arrhythmogenic right ventricular cardiomyopathy. A-C. 4-chamber, short-axis, and 2-chamber views of different patients with hypertrophic cardiomyopathy; B and C, imaging taken after administration of gadolinium, showing extensive areas of delayed enhancement (white) in the septum and apex, respectively; D, 4-chamber view of a dilated cardiomyopathy; E-F, 2- and 4-chamber views of a patient with arrhythmogenic right ventricular cardiomyopathy, with arrows indicating a massively dilated right ventricle and fat and fibrotic infiltration. Adapted with permission.²²

systolic dysfunction. Compared to HCM, DCM is a less common cause of SCD in athletes (approximately 3%),²⁴ probably because of its lower prevalence and the higher tendency for exercise intolerance owing to more substantial mechanical deficits. The genetic mutations linked to DCM thus far account for about 30% of cases of idiopathic DCM, and clinical genetic testing is available.

Arrhythmogenic right ventricular dysplasia (ARVD) or cardiomyopathy (ARVC) is an inherited heart muscle disease that affects between 1 and 2000-5000. It is characterized by fibrofatty replacement of the myocardium, classically involving the right ventricle (Figures 3E and 3F).^{13,14} Recent reports show left ventricle involvement in more than 80% of cases, involvement that may precede that of the right ventricle.^{18,48} ARVD is associated with a significant risk of SCD. In the United States, ARVD accounts for approximately 3% of SCDs in young athletes but for a much greater percentage in the Veneto region in Italy (about 25%).¹² The reasons for this discrepancy are unclear but may be related to a unique genetic or morphologic substrate in the latter region and/or a disproportionate recognition of HCM through the mandatory national screening program in Italy, which has disqualified athletes with HCM. Diagnosis is more challenging than that for other cardiomyopathies and so frequently requires special imaging techniques such as cardiac MRI. ARVD is caused by mutations in genes that encode for proteins of the cardiac desmosome,⁵⁴ which functions to maintain structural adhesion

(and probably electrical communication) between cardiac muscle cells.^{36,37} Clinical genetic testing has recently become available for ARVD.

The Prevalence of Cardiomyopathies in Athletes

Estimates of the prevalence of cardiomyopathies in athletes are limited, in part because not all countries share a systematic, uniform screening mechanism. Two recent studies reported the prevalence of HCM to be between 0.06% and 0.07% in large European populations of competitive athletes.^{6,12} An explanation for the lower prevalence of HCM in athletes compared to that of the general population (0.2%) is not readily apparent but may be due to selection against individuals with HCM who cannot meet the cardiovascular demands of strenuous exercise. Note too that the study populations in both these European studies were predominantly Caucasian and that the prevalence of HCM in athletes of a more racially diverse background has not been established. The prevalence of other cardiomyopathies is not known, but it is likely to be much lower than that of HCM. DCM was not found during routine screening in either of the 2 studies, but it was found on postmortem examination in 1 athlete (out of 33 735 total) who suffered SCD in an Italian cohort. ARVD was not identified in any athletes in preparticipation screening, but it was responsible for 11 SCDs in the Italian study, indicating that the prevalence of ARVD in athletes is close to that of the general population, at 1 in 3000.

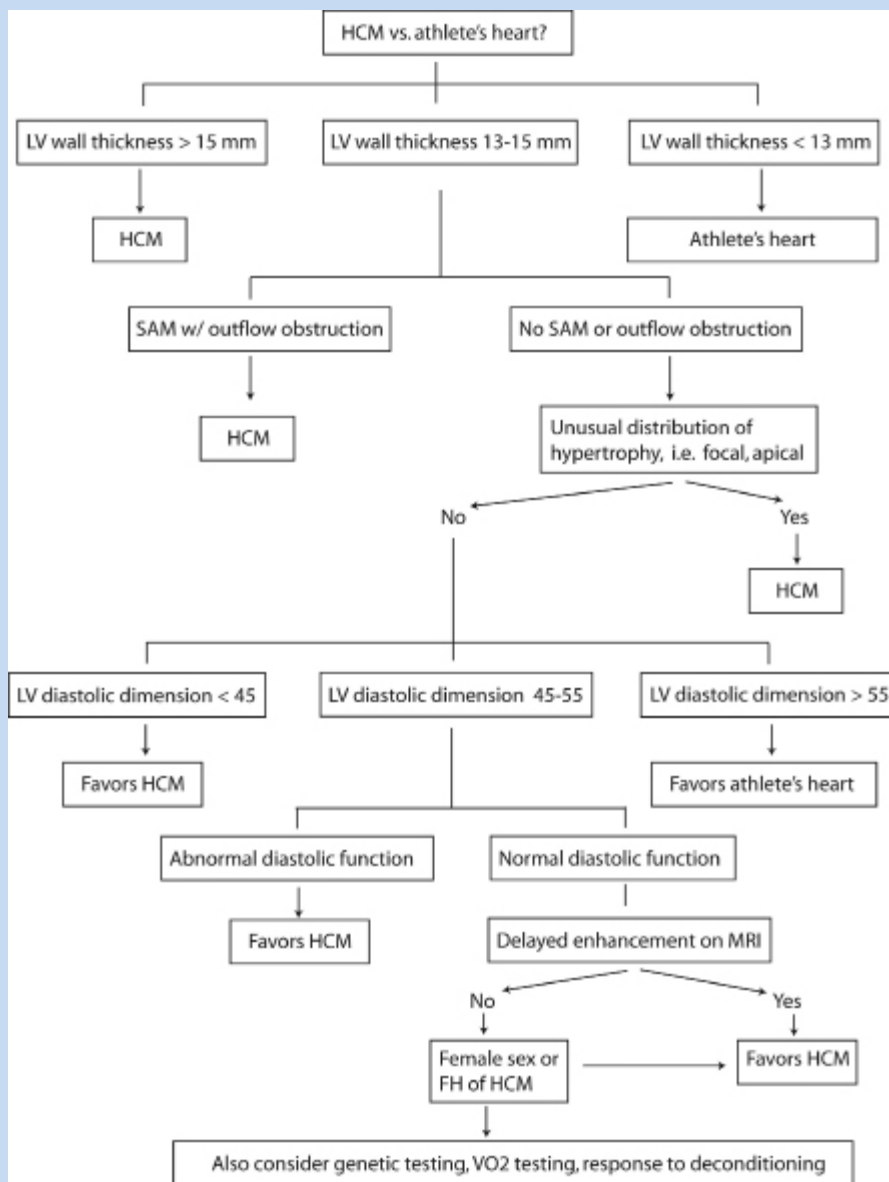


Figure 4. Decision tree for differentiating hypertrophic cardiomyopathy (HCM) from athlete's heart. LV, left ventricle; SAM, systolic anterior motion; FH, family history.

Discriminating HCM From Athlete's Heart

The differential diagnosis between athlete's heart and HCM has critical implications. Missing the diagnosis of HCM in athletes and allowing them to continue to compete may put them at risk of SCD. Conversely, an incorrect diagnosis of HCM may lead to unnecessary disqualification from competitive sports, with significant physical, emotional, and possibly financial repercussions.

The athlete's heart is characterized by mild concentric left ventricular hypertrophy and mild dilation of the left ventricle cavity. Several studies have described the physiological limits of the morphological changes that occur in the normal heart

of a competitive athlete,^{1,40,50,53} beyond which an alternate pathologic diagnosis should be considered. In the athlete's heart, wall thickness greater than 12 mm in any segment is rare, at least in white athletes (< 1%-8%). Wall thickness greater than 15 mm has not been observed in any white athletes, even professional cyclists from the Tour de France.¹ However, a recent study showed that professional black athletes attain greater wall thickness compared to that of white athletes, with 3% measuring 15 mm or more.⁵ These new data need to be taken into consideration when using the decision tree presented in Figure 4 or any previously published algorithm. The first branch point concerns absolute wall thickness; if it exceeds 15 mm in any segment, this is

diagnostic for HCM, at least in white athletes (in the absence of another cause for hypertrophy). Conversely, wall thickness less than 13 mm is most consistent with an athlete's heart, although HCM can manifest with mild hypertrophy. A family history of HCM in an athlete with minimal hypertrophy should therefore prompt further investigation. The so-called gray zone exists at a wall thickness between 13 and 15 mm, where it is often challenging to distinguish the 2 diagnoses. The presence of systolic anterior motion of the mitral valve, particularly if associated with dynamic left ventricular outflow obstruction at rest or with upright exercise, is a pathologic finding that indicates a diagnosis of HCM. Another distinguishing pathologic characteristic is the distribution of hypertrophy; unusual asymmetric or focal hypertrophy, such as an apical variant, would strongly suggest the diagnosis of HCM.

In the absence of any of the above findings, further morphological and functional characterization of the left ventricle is necessary. Athlete's heart typically causes left ventricle chamber dilation (> 55 mm, exceeding 70 mm at the extreme⁶) whereas HCM is usually associated with a smaller chamber size (< 45 mm). The ejection fraction tends to be normal or even mildly decreased in athlete's heart^{1,50,53} but is characteristically greater than normal in HCM patients. However, diastolic function should be normal in the athlete's heart, but it is usually abnormal in HCM. Echocardiography to assess conventional Doppler mitral valve inflow patterns, coupled with tissue Doppler and newer techniques such as 2-dimensional strain rate imaging, can reliably distinguish normal diastolic function in the athlete's heart from diastolic dysfunction in HCM.^{7,19,20,44,47,52} Cardiac MRI can also be a valuable tool in differentiating the athlete's heart and HCM. First, it provides precise left ventricular geometric and volume measurements. Second, delayed uptake of gadolinium into the myocardium (referred to as *delayed enhancement*) is indicative of fibrosis, which is a pathologic finding observed in approximately 70% of patients with HCM.³⁵ The presence of delayed enhancement strongly favors HCM over a physiologic process.

Additional factors that favor HCM include female sex (ie, female athletes develop less physiologic hypertrophy than do men at a comparable level of training) and family history of HCM. Genetic testing can be considered in situations where there is still diagnostic uncertainty. A negative genetic test result is not helpful, given that 30% to 55% of patients with established HCM will not carry a mutation in any of the 11 genes in the test panel. Identifying a known pathogenic mutation is strongly supportive of HCM but may require familial testing for confirmation. Higher peak oxygen consumption (> 50 or > 20% above predicted maximum) measured during cardiopulmonary exercise testing favors the diagnosis of athlete's heart,⁴⁹ but this parameter is less useful in strength athletes such as bodybuilders.⁴ Finally, reversibility of left ventricular hypertrophy after a period of deconditioning strongly favors the diagnosis of athlete's heart, given that pathologic hypertrophy would not be expected to regress with cessation of exercise. With deconditioning, an athlete's heart should return to normal wall thickness, but about 20% of athletes will show persistent cavity dilatation (> 60 mm), even years after ceasing competition.³⁹ The length of

time required to see the effects of deconditioning are typically more than 3 months, but as few as 6 weeks may be sufficient to observe hypertrophy regression.²⁷ Convincing an elite athlete to completely stop exercising for any period is often met with resistance on the part of the athlete or team, but when diagnostic uncertainty exists, it is probably the most definitive means of excluding the diagnosis of HCM. Cardiac MRI would provide the most accurate before- and after-detraining comparison of hypertrophy and geometric indices.

CONCLUSION

Recognizing cardiac conditions that can lead to SCD in athletes is of paramount importance to sports medical personnel. Preparticipation screening with at least a history and a physical should be performed in all athletes, whereas the use of the ECG is still controversial. Attention needs to be paid to the challenges in diagnosing inheritable cardiomyopathies and in some instances distinguishing them from physiologic changes associated with the athletic heart. Among many areas, further studies are needed to determine the benefit of screening all children participating in routine physical education and the cost-effectiveness and feasibility of ECGs for preparticipation screening.

NOTE

The second part of this article, "Cardiovascular Health, Part 2: Sports Participation in Athletes With Cardiovascular Conditions," will appear in the January/February 2010 issue of *Sports Health*.

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