REVIEW

CME CREDIT

THOMAS M. MICK, MD
Section of Sports Medicine, The Cleveland Clinic Foundation

ROBERT J. DIMEFF, MD
Section of Sports Medicine, The Cleveland Clinic Foundation

What kind of physical examination does a young athlete need before participating in sports?

ABSTRACT

Recommendations exist for preparticipation physical examinations, but there is no national standard, and the recommendations are not widely followed. The most common reasons for denying clearance to play are musculoskeletal conditions, hypertension, and visual acuity problems. Although detecting potentially life-threatening conditions is an appropriate goal, preparticipation physical examinations have only a limited ability to detect cardiac abnormalities that dispose athletes to sudden death on the playing field; fortunately, these events are very rare.

KEY POINTS

The primary goals of the preparticipation physical examination are to detect conditions that may predispose to injury, disability, or death and to meet legal and insurance requirements.

The secondary goals of the preparticipation physical examination are to determine the general health of the athlete, provide counsel on health-related issues, and assess the athlete's fitness for specific sports.

Parents and athletes should be made aware that the preparticipation physical examination does not eliminate the risk of all potentially lethal cardiovascular disease.

The American Heart Association does not recommend electrocardiography or echocardiography as a routine part of the preparticipation physical examination.

EVERY YEAR, millions of high school and college students play a sport—6.7 million high school students in the 2000–2001 season alone, according to the National Federation of State High Schools. In all states but Rhode Island, these athletes were required to receive a preparticipation physical examination—at least partly in the hopes of detecting cardiac conditions that could predispose them to sudden death.

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Despite the large number of preparticipation physical examinations performed every year, many exams are inadequate. In this article, we will discuss the recommendations for screening and the advantages and disadvantages of different types of screening, from one-on-one exams to mass screenings.

Nonetheless, even when exams are performed according to guidelines, the history and physical exam does not guarantee that all potential cardiac anomalies will be detected, a fact parents and athletes need to understand.

TWO SETS OF RECOMMENDATIONS

Despite the large numbers, no national standard exists for these examinations. The content of the examination varies from state to state, and so does the person allowed to perform it. In 21 states, nurses and physician assistants can perform the examination, and in 11 states, so can chiropractors.[1]

TABLE 1

Recommendations for cardiovascular screening during preparticipation examinations

Athletic screening should be performed by a health care worker with the requisite training, medical skills, and background to reliably obtain a detailed cardiovascular history, perform a physical examination, and recognize heart disease.

The screening should include a complete medical history and physical examination that includes brachial artery blood pressure measurement.

The cardiovascular history should include questions designed to determine the prior occurrence of:

- Exertional chest pain or discomfort
- Syncope or near syncope
- Excessive, unexpected, and unexplained shortness of breath with exercise
- The past detection of a heart murmur or elevated blood pressure
- A family history of premature death (sudden or otherwise)
- Significant disability from cardiovascular disease in close relatives younger than 50 years
- Specific knowledge of the occurrence of hypertrophic cardiomyopathy, Marfan syndrome, arrhythmias, long QT syndrome, or dilated cardiomyopathy

Parental involvement in completing the history portion for high school students should be encouraged.

The cardiovascular examination should emphasize the assessment of:

- Femoral artery pulses to exclude coarctation of the aorta
- Precordial auscultation in the supine and standing positions to identify heart murmurs consistent with dynamic left ventricular outflow obstruction
- Recognition of the physical stigmata of Marfan syndrome
- Brachial blood pressure measurement in the sitting position.

ADAPTED FROM MARON BJ, THOMPSON PD, PUFFER JC, ET AL. CARDIOVASCULAR PREPARTICIPATION SCREENING OF COMPETITIVE ATHLETES: A STATEMENT FOR HEALTH PROFESSIONALS FROM THE SUDDEN DEATH COMMITTEE AND CONGENITAL CARDIAC DEFECTS COMMITTEE, AMERICAN HEART ASSOCIATION. CIRCULATION 1996; 94:850–856 (ADDENDUM PUBLISHED IN CIRCULATION 1998; 97:2294).

The goal is to help athletes participate safely in sports

Nevertheless, there are two sets of recommendations on the proper performance of preparticipation physical examinations:

- A monograph from five medical societies (the American Medical Society for Sports Medicine, the American Academy of Family Physicians, the American Academy of Pediatrics, the American Orthopaedic Society for Sports Medicine, and the American Osteopathic Academy of Sports Medicine),[2] produced in an attempt to set a standard, which provides a useful form for physicians to complete.
- A consensus statement on cardiovascular screening from the American Heart Association (AHA).[3]

WHAT IS THE PURPOSE OF THE EXAM?

According to the five-society monograph,[2] the primary goals of the examination are to detect conditions that may predispose to injury, disability, or death and to meet legal and insurance requirements.

The secondary goals are to determine the general health of the athlete, to counsel the athlete on health-related issues, and to assess the athlete's fitness for specific sports.

In general, the philosophy is to help athletes participate safely in sports rather than to exclude them. If a medical condition makes it unsafe for an athlete to participate, he or she can be held out of the sport either until the problem is corrected or indefinitely if the problem is sufficiently serious.

The preparticipation physical examination is not meant to be a regular health maintenance visit, but physicians can take advantage of the opportunity to discuss health maintenance topics such as seat belt use, tobacco use, safe sex, and birth control—if there is time. Usually, however, there is no time.

Nevertheless, the preparticipation physical examination is the only yearly health

examination that some children ever receive. In a study of 701 Connecticut high school students,[4] 234 (44%) reported that the school sports examination was their only health assessment in 2 years. In another study, 88% of 557 Texas high school athletes reported that the preparticipation physical examination was their only source of routine health care.[5]

Detecting life-threatening conditions

For adolescent athletes, the most common cause of death during sports activities is congenital cardiovascular disease. According to the National Center for Catastrophic Sports Injury Research,[6] cardiovascular conditions accounted for 100 of the 136 nontraumatic athlete deaths that occurred between 1983 and 1993. Of these deaths, 51 were due to hypertrophic cardiomyopathy and 16 were due to anomalous coronary arteries.

In view of these rare but tragic deaths, the AHA committee[3] specifically recommended that cardiovascular screening be included in the preparticipation physical examination, that the examination be standardized, and that it be performed by physicians who are knowledgeable about cardiovascular disease (TABLE 1). Whether physicians can hope to detect conditions that predispose to sudden cardiac death is not known, however.

MANY EXAMS FALL SHORT

The examinations that many high school and college athletes receive do not meet these recommendations. As of 1998, eight states had no standardized questionnaires for the history and physical examination, and one state had no formal screening requirement at all. Twelve states had screening forms that were judged to be inadequate (containing four or fewer of the AHA screening questions). In sum, 20 states had either no standardized preparticipation physical examinations or inadequate guidelines.[7]

In 1999, Gomez et al[8] analyzed the preparticipation physical examination forms from 254 high schools and found that 47 (25.3%) included questions about exercise-related symptoms, 97 (52.2%) included questions about a previous diagnosis of murmur or high blood pressure, and 57 (30.7%) had questions about a family history of early myocardial infarction or sudden death. Only 32 (17.2%) asked all three questions, which are part of the recommended cardiac screening.

The situation in colleges is similar. In 2000, Pfister et al[9] assessed the success of the AHA guidelines in 1,110 National Collegiate Athletic Association (NCAA) colleges. The response rate was 79%. A screening was considered adequate if nine of the 12 AHA-recommended items were included; it was considered inadequate if it contained four or fewer of the 12 items. Twenty-six percent of the programs were deemed adequate, 50% were intermediate, and 24% were inadequate.

WHEN SHOULD THE EXAM BE DONE?

The five-society monograph[2] recommends that the preparticipation physical examination be performed 6 weeks before preseason practice begins, to allow time for any problem to be corrected or rehabilitation to take place. After the full, initial screening preparticipation physical examination, interim examinations are recommended. Some experts believe that full screening should occur yearly, and others believe that an annual history and a focused physical examination is appropriate for athletes with abnormal findings.[2]

The sports physical is the only yearly examination some children receive

The AHA suggests that a comprehensive personal and family history be obtained from the athlete upon entering high school or college. In each of the subsequent 3 to 4 years, an interim history and blood pressure measurement should be obtained. Important changes in medical status or abnormalities detected during interim annual histories may signal that another physical examination and further testing should be performed. High school athletes should receive a complete physical examination every 2 years.[3]

THREE TYPES OF EXAMINATIONS

There are three types of preparticipation physical examinations: office-based, assembly line, and station. It is unclear if one system is better than another. Each physician must make his or her own judgment about the system to

use. Whichever type is chosen, it is imperative to perform the cardiac examination in a quiet environment, given that undiagnosed heart disease is the leading cause of death in athletes.

Office-based examination

One approach is for the athletes to see their primary care physicians in the office. This system is advantageous because the physician is familiar with the patient and may have more time and privacy for counseling about sensitive issues. The disadvantages include a lack of continuity from year to year if the athlete changes physicians, time restraints, possible lack of expertise, high cost, and possible communication problems.

Assembly line examination

This method, in which a single physician examines a large number of athletes in sequence, is low in cost and requires less time. Disadvantages include possible communication problems, lack of individual attention, possible insufficient history taking, and lack of continuity from year to year if different physicians are used.

Parents should help fill out the medical history form

Station examination

This type, in which multiple examiners perform discrete functions in sequence, is cost-effective and efficient and allows for more access, better communication, and the use of physicians with specialized expertise. The disadvantages include noise and confusion, possible compromised care, lack of privacy and time, and possible communication problems.

COMPONENTS OF THE EXAM

Medical history

Parents should help fill out the medical history form, because athletes often provide different information than parents do: eg, the athletes tend to omit important information, and the parents are more knowledgeable about family history. The form should ask about recent or chronic problems, hospitalizations, surgical procedures, prescription and nonprescription medications, and allergies or anaphylactic reactions to medications, insects, and exercise. It should also inquire about all of the different systems of the body, starting with the heart.

Heart. The form should follow the AHA guidelines[3] in asking about:

- Chest pain or chest discomfort
- Syncope or near syncope
- Excessive, unexpected, and unexplained shortness of breath or fatigue associated with exercise
- Past detection of a heart murmur or high blood pressure
- A family history of premature death or significant disability from cardiovascular disease in close relatives younger than age 50
- Hypertrophic cardiomyopathy, dilated cardiomyopathy, Marfan syndrome, long QT syndrome, and arrhythmia.

Skin: warts, fungus, or blisters.

Neurologic disorders: headaches, concussions, and seizures. A recent history of concussion is different than a remote history of concussion, but there is no consensus about the appropriate evaluation of patients who have had multiple remote concussions. Neuroimaging and neuropsychological testing can be used to evaluate athletes with recent or remote concussions. If the concussion was recent, the athlete should be held out of sports until he or she has no symptoms with exercise.[10]

Heat illness.

Use of special equipment.

Asthma and seasonal allergies. Asthma is the most common chronic illness of adolescents. Of those affected, 85% have exercise-induced bronchospasm. The prevalence of exercise-induced bronchospasm is believed to be 10% to 35% of athletes. It should be suspected in any athlete who has a history of wheezing during sports.[11]

Eyes. The athlete should have adequate vision for the sport. The history and physical should also determine if the athlete is functionally one-eyed, defined as having less than 20/40 corrected vision in one eye.

Musculoskeletal system: sprains, strains, fractures, and dislocations that required treatment or rehabilitation. Musculoskeletal injury patterns of concern vary by sport. Fractures and ligament injuries are more common in high-contact or collision sports. Low-contact or endurance athletes are more likely to have

a history of overuse injury, tendonitis, or stress fractures.

Weight concerns. Eating disorders or problems with body perception are most prevalent in sports that have weight classes or emphasize appearance or leanness for improved performance. Some studies have shown that as many as 62% of female athletes have an eating disorder.[12]

Psychosocial issues: alcohol, drugs, tobacco, steroids, and sexual practices.

Immunizations. The athlete should be current on immunizations against tetanus, measles, hepatitis B, and varicella.

Menstruation. Primary amenorrhea (absence of menses by age 16) or secondary amenorrhea (absence of menses for more than three cycles) suggests the female athlete triad (eating disorder, amenorrhea, and osteopenia).

TABLE 2

Classification of adolescent hypertension

AGE	BLOOD PRESSURE (MM HG)		
	HIGH NORMAL	SIGNIFICANT HYPERTENSION	SEVERE HYPERTENSION
13–15			
Systolic	124–135	136–143	> 143
Diastolic	77–85	86–91	> 91
16–18			
Systolic	127–141	142–149	> 149
Diastolic	80–91	92–97	> 97

ADAPTED FROM AMERICAN ACADEMY OF PEDIATRICS COMMITTEE ON SPORTS MEDICINE AND FITNESS. ATHLETIC PARTICIPATION BY CHILDREN AND ADOLESCENTS WHO HAVE SYSTEMIC HYPERTENSION. PEDIATRICS 1997; 99:637–638

Physical examination

Athletes must have a thorough physical examination that assesses the entire body's fitness for sports.

Height, weight, and vital signs. Take the athlete's brachial blood pressure while he or she is sitting. The sphygmomanometer bladder should encircle at least two thirds of the arm—the most common cause of an abnormal value is improper cuff size. If the initial value is elevated, two subsequent readings should be obtained before making the diagnosis of hypertension. Hypertension in the adolescent can be a marker of endocrinologic, renal, cardiac, or central nervous system abnormalities or substance abuse.

Extensive data on blood pressure are not available for children in the United States, but standards have been developed by the Task Force on Blood Pressure Control in Children of the National Heart, Lung, and Blood Institute, part of the National Institutes of Health.[13] These standards differ according to gender and height. We recommend using TABLE 2, which is a simplification of these standards developed by the American Academy of Pediatrics Committee on Sports Medicine and Fitness.[14]

Eyes, ears, nose, and throat. Measure visual acuity and equality of pupils, and conduct a general examination of the ears, nose, oral cavity, and neck. Poor dentition may indicate an eating disorder. A high, arched palate can be a sign of Marfan syndrome.

Heart. Auscultate the chest with the athlete supine, standing, and using the Valsalva maneuver. Listen for murmurs consistent with dynamic left ventricular outflow obstruction (ie, that increase upon standing). Such murmurs indicate hypertrophic cardiomyopathy or mitral valve prolapse. To further differentiate the murmurs, have the athlete perform a sustained hand grip; in hypertrophic cardiomyopathy, the murmur becomes softer; in mitral valve prolapse, it becomes louder.

Assess the femoral arteries to exclude aortic coarctation.

Look for the stigmata of Marfan syndrome: disproportionately tall stature, thoracic deformity, joint contracture or laxity, subluxation or dislocation of the lens (ectopia lentis) and myopia, aortic dilation and dissection, and mitral valve prolapse.

Pulmonary auscultation. Remember that a normal examination does not preclude the possibility of exercise-induced bronchospasm.

Abdominal palpation. This assessment checks for pregnancy in female athletes and the health of the liver and spleen. Splenic rupture occurs in the first 3 to 4 weeks of the onset of systemic signs of infectious mononucleosis. If splenomegaly is suspected, ultrasound or computed tomography should be used to evaluate the size of the spleen.[15]

Genitalia. Assess for single testicle, hernia, and undescended testicles. Tanner staging

A normal pulmonary examination does not preclude exercise-induced bronchospasm

of sexual development is not recommended.

Skin. Evaluate the skin for rashes, infections, and infestations. Increased acne on the back may indicate steroid use.

Musculoskeletal system. If there is a history of injury to the musculoskeletal system, perform an examination specific to the problem. Otherwise, the following maneuvers should be performed:

- Inspection
- Forward flexion, extension, and lateral flexion of the neck
- Resisted shoulder shrug
- Internal and external rotation of the shoulders
- Resisted shoulder abduction
- Extension and flexion of the elbows
- Pronation and supination of the elbows
- Fist clench and finger spread
- Inspection of the back
- Back extension
- Back flexion
- Inspection of the lower extensors
- Duck walk
- Standing on toes.

Neurologic examination should be performed only if the musculoskeletal examination is abnormal or if the patient has a history of concussion with symptoms.

Athletes with arrhythmias should be referred to a cardiologist

CLEARANCE AND NONCLEARANCE

After the preparticipation physical examination, a physician typically assigns the athlete into one of three categories:

- Cleared to play with no restrictions
- Cleared to play following further evaluation, treatment, or rehabilitation
- Not cleared to play certain types of sports.

In general, it is rare for athletes not to be cleared. Smith and Lakowski[16] compiled data from nine large-scale studies of preparticipation physical examination of 26,247 athletes and examined the rates on nonclearance. Only 249 of the 26,247 athletes screened were not cleared. The range of disallowed athletes in the study was between 0 and 2.6%.

In their own series,[16] Smith and Lakowski found that 1.9% of 2,729 high school athletes were ruled ineligible as a result of the preparticipation physical examination. Musculoskeletal abnormalities accounted for the largest number of nonclearances, and cardiac abnormalities (18.9%) and vision limitations (13.2%) were the next highest.

In a study of 10,000 athletes, Magnes et al[17] reported that abnormalities associated with hypertension and vision were the leading causes for referral and disqualification.

Conditions that can limit participation

A variety of abnormalities can make it unsafe for an athlete to participate in sports. A familiarity with these abnormalities and the limitations they might confer is crucial.

Drug use. Know the regulations of the organization under which the athlete competes.

Acute illness. Diagnosis of acute illness relies on individual assessment, and clearance to play depends on the likelihood of the illness worsening or being spread with participation. Athletes with fever or diarrhea need to have a high fluid intake to prevent dehydration.

Blood-borne pathogens. Athletes with HIV may participate unless their health is compromised. The risk of transmission is thought to be less than 1 in 1,000,000 games.[15]

Heart disease. Follow the recommendations set forth by the 26th Bethesda Conference.[18] Refer the athlete to a cardiologist if a murmur is detected or an abnormality suspected. An athlete who has hypertension but no end-organ damage may participate. Severe hypertension (TABLE 2) requires removal from athletics until control is achieved.[14]

A wide pulse pressure with systolic hypertension suggests aortic valve insufficiency, patent ductus arteriosus, or an atrioventricular malformation. A benign functional murmur and mild mitral valve prolapse are not reasons for disqualification, but pathologic murmurs (ie, diastolic, grade 3/6 or more systolic, holosystolic, abnormal splitting of S2 or S4, or harsh murmurs) and moderate to severe mitral valve regurgitation need to be carefully evaluated.

Other red flags include syncope secondary to arrhythmia, a family history of sudden death secondary to mitral valve prolapse, an embolic event, and arrhythmia that is worse with exercise.

Athletes with arrhythmias should be

referred to a cardiologist. Athletes with hypertrophic cardiomyopathy should not be cleared to play unless the sport is of low intensity. However, the leading disqualifiers are rhythm and conduction abnormalities, systemic hypertension, and valvular heart disease rather than hypertrophic cardiomyopathy.

Skin. Athletes with contagious lesions or skin conditions should not participate in sports that require the use of mats or the sharing of helmets.

Eating disorder/female athlete triad. Participation of athletes with these disorders requires a multidisciplinary approach and cooperation of the athlete and coach.

Eyes. Refer an athlete with an eye condition that has required surgery to an ophthalmologist for clearance. The American Academy of Pediatrics and the American Academy of Ophthalmology recommend mandatory protective eyewear for functionally one-eyed athletes and those who have had surgery or trauma. A functionally one-eyed athlete can participate only in sports that permit the use of protective eyewear and do not involve projected objects (eg, swimming, track and field, gymnastics). Wrestling, boxing, and martial arts are contraindicated for these athletes.[19]

Gynecology. Athletes with a menstrual disorder may be cleared while the evaluation is in process. Pregnant athletes may not be cleared for contact, collision, or strenuous sports.

Heat illness. Athletes with recurrent heat illness may be cleared if the cause is secondary to obesity, medication, dehydration, febrile illness, or insufficient acclimation and is corrected. Those with a history of heat stroke or heat-related rhabdomyolysis may have restricted clearance. Physicians can screen for a tendency toward exertional hyperthermia by asking about a history of heat-related illness. Athletes with this condition are usually allowed to participate, but temperature extremes must be avoided, and hydration must be ensured.

Hepatomegaly or splenomegaly. An athlete with acute hepatomegaly should be disqualified until the condition resolves. Splenomegaly is a contraindication to participation.

Inguinal hernia. Athletes with no symptoms can participate fully.

Kidney abnormalities. Athletes with only one kidney should be referred to a nephrologist for evaluation. The American Academy of Pediatricians recommends that such athletes do not participate in high-contact sports. A flack jacket should be used for moderate-contact sports.[20]

Musculoskeletal disorders. Clearance is made on the basis of the degree and type of injury, the risk to the athlete, and the demands of the sport. Padding, taping, and other preventive measures should be considered. Athletes who receive treatment and rehabilitation must be reevaluated before they are cleared.

Neurologic disorders. Return to play after a concussion remains controversial.[21–23] In general, athletes are ready to play when they have no symptoms with exercise, a normal neurologic examination, and have returned to baseline neuropsychological functioning.

Athletes with brachial plexus injuries that have fully resolved may be cleared. Full resolution requires a pain-free range of motion and normal sensory and motor examinations. If unresolved, flexion, extension, anteroposterior, lateral, and open-mouth odontoid cervical spine radiographs are required.

A spine specialist should evaluate cervical spinal neuropraxia and transient quadriplegia.

Seizure disorder is not a contraindication to sports participation if the seizures are well controlled. However, any athlete who has had one or more seizures in the last 6 months should be withheld from competition, especially high-risk competition (eg, skiing, gymnastics, high diving, collision sports, shooting, archery). These athletes should be evaluated by a neurologist.[20]

Lungs. Asthma is not a contraindication to participation as long as symptoms are well controlled.

Athletes with pulmonary insufficiency (ie, forced expiratory volume in 1 second < 50%) require further evaluation to rule out pulmonary hypertension or cor pulmonale.

Sickle cell trait or disease carries no restrictions under normal conditions.

Sickle cell trait or disease usually carries no restrictions on sports participation

Testicles. Athletes with a unilateral testis must wear a protective cup. Those with an undescended testicle should be informed of the increased risk of cancer and referred to a urologist.

MEDICOLEGAL CONSIDERATIONS

Parents and athletes should be made aware that the preparticipation physical examination does not eliminate the risk of all potentially lethal cardiovascular disease. To reduce the chance of lawsuits, physicians need to follow available recommendations or guidelines or be ready to defend their decision if they choose not to do so.

According to Mitten,[24] an attorney at the National Sports Law Institute, a physician can deviate from the guidelines when medical factors justify it, but he or she should document the reasons for this deviation. Courts generally will not enforce waivers of legal rights to release physicians from liability for negligent care. Such a waiver is legally unenforceable because it creates an incentive for physicians to avoid complying with their legal duty to adhere to accepted medical practice.

Physicians need to follow examination guidelines or be ready to defend their decision not to do so

Both the Americans with Disabilities Act of 1990 and the Rehabilitation Act of 1973 prohibit unjustified discrimination against people who have physical deformities or impairments. These acts form the foundation of the legal argument against disallowing an athlete's participation on the basis of a doctor's evaluation. The legal framework in this area is still developing, but several decisions seem to support a physician's right to exclude athletes with conditions that expose them to an increased risk of significant harm (eg, *Knapp v Northwestern*, 1995).[25]

Avoiding charges of sexual harassment

Because most preparticipation physical examinations will be done without an ongoing doctor-patient relationship, it is important that the physician inform the athlete beforehand that the exam will be thorough. Consistency with the examination and clothing is imperative. We suggest that male athletes be instructed to wear shorts and a T-shirt and that female athletes wear shorts and a jogging bra.

'Good Samaritan' laws

Some states give physicians who do not charge fees for performing preparticipation physical examinations protection under this statute. However, the protection does not apply if the physician receives compensation.

DOES SCREENING PREVENT CARDIOVASCULAR DEATH?

There are no prospective studies of whether the preparticipation physical examination, if performed according to the two sets of recommendations,[2,3] effectively screens out cardiovascular conditions that predispose to sudden death. If the national guidelines were followed, perhaps the rate of sports-related cardiac sudden death would decline. However, there is not much reason to believe screening would be completely effective.

In fact, the AHA[3] states that screening by history-taking and physical examination alone (without noninvasive testing) is insufficient to guarantee detection of many critical cardiovascular abnormalities in large populations of young athletes.

They go on to say that detection of hypertrophic cardiomyopathy by standard screening is unreliable because 75% of patients have the nonobstructive form of the disease, which is characterized by a soft murmur or none at all. Furthermore, most athletes with hypertrophic cardiomyopathy do not experience syncope and do not have a family history of premature sudden death due to the disease.

The standard physical examination has a low specificity for detecting many cardiovascular abnormalities that lead to sudden cardiac death in young athletes, particularly those associated with symptoms such as chest pain or impaired consciousness. Across the broad disease spectrum of hypertrophic cardiomyopathy, the physical examination may not be a reliable method for clinical identification, given that most patients do not have left ventricular tract outflow obstruction and most of the well-documented physical findings (eg, loud systolic heart murmur, bifid arterial pulse) are limited to patients with outflow tract gradients.[26]

Neither is the history very sensitive. Maron et al[27] found that only 25% of athletes

with hypertrophic cardiomyopathy who died of sudden cardiac death had a family history of one or more nontraumatic familial deaths at age 50 or younger.

In another study, Maron et al[28] retrospectively reviewed 158 sudden deaths in young athletes from 1985 through 1995. They found that 134 had a cardiac cause of death, 48 due to hypertrophic cardiomyopathy. In these 48 athletes, symptoms and history provided a clue to the ultimate diagnosis in only 20%. In the same study, 13 athletes died from an anomalous left main coronary artery; only 4 (31%) had symptoms (usually syncope or dizziness).

The ability to detect severe cardiac disease that might lead to death is only marginally improved by the addition of noninvasive testing. In one study in which electrocardiography did not detect more potentially fatal cardiac conditions, Fuller et al[29] added electrocardiography to the prospective screening of 5,615 high school athletes. Twenty-two athletes were determined to have serious conditions as defined by the 16th Bethesda Conference. A serious condition is one that requires further evaluation with testing, such as echocardiography; it does not necessarily mean that the condition leads to sudden cardiac death.

In the Fuller study,[29] taking a cardiac history led to detection of a serious condition in no athletes; 6 received a diagnosis after physical examination (one auscultation, five blood pressure measurements), and 16 were identified by electrocardiography (5 with premature ventricular beats, 6 with ventricular preexcitation, 4 with right bundle-branch block, and 1 with supraventricular tachycardia). The athlete with supraventricular tachycardia received ablation and was able to return to participation. The other 15 athletes identified with rhythms that needed further evaluation were not assessed further as part of the study. One athlete who was allowed to participate after normal history, physical examination, and electrocardiogram later had a ventricular fibrillation arrest due to an anomalous right coronary artery. Of the 22 athletes withheld, none had conditions that predisposed to sudden cardiac death during exercise. Thus, in this screening study, 22 athletes were withheld because of conditions not commonly associated with sudden cardiac death, and 1 athlete had an undetected condition that commonly is associated with sudden cardiac death in young athletes.

In a much larger study,[30] more extensive testing lead to a decrease in the death rate due to hypertrophic cardiomyopathy. Corrado et al[30] screened 33,735 young athletes from 1979 to 1996 using history, physical examination, and electrocardiography. They documented 49 sudden deaths in athletes and 240 sudden deaths in a nonathletic control group during the same period. Hypertrophic cardiomyopathy was detected in 22 athletes (0.07%) during preparticipation physical examination screening and accounted for 3.5% of the cardiovascular reasons for disqualification. None of the disqualified athletes with hypertrophic cardiomyopathy died during the mean follow-up of 8.25 years. Hypertrophic cardiomyopathy caused one sudden cardiac death among the athletes (2%) but caused 16 cardiac deaths in the nonathletes (7.3%). Using extensive screening and vigorous follow-up, they were able to decrease the death rate from hypertrophic cardiomyopathy.

For adolescent athletes, the most common cause of death is congenital heart disease

Interestingly, in the North American studies, the most common causes of death in athletes were hypertrophic cardiomyopathy (36%), coronary artery anomalies (19%), and idiopathic left ventricular hypertrophy (10%).[27] In the study by Corrado et al,[30] which took place in Italy, the most common causes of sudden death in athletes were arrhythmogenic right ventricular cardiomyopathy (22.4%), coronary atherosclerosis (18.4%), and anomalous origin of a coronary artery (12.2%). The reason for this regional variation is unclear.

Several objections are often made to using electrocardiography and echocardiography as screening tools. One objection is that electrocardiography is sensitive but not specific and thus may lead to false-positive results. Evidence of this can be found in a study by Pelliccia et al,[31] who evaluated 1,005 world-class athletes (785 in routine yearly screening and 220 for suspected cardiovascular abnormalities) using history, physical examination, electrocardiography, and follow-up echocardiography when indicated. They found that 40% had abnormal electrocardiograms (14%

had distinctly abnormal electrocardiograms and 26% had mildly abnormal ones) indicative of physiologic cardiac remodeling. Potentially lethal disorders were detected in only five athletes with abnormal electrocardiograms, and abnormalities of any level were documented in only 5% of those with abnormal electrocardiograms. Of note, females usually had normal or virtually normal electrocardiograms.

The investigators concluded that an important subset of their population without cardiac morphologic alterations had striking electrocardiographic abnormalities highly suggestive of cardiac disease that were likely an innocent consequence of athletic training and part of "athlete's heart syndrome." Such false-positive results, the investigators concluded, may limit routine electrocardiographic testing as part of the preparticipation physical examination. However, normal electrocardiographic results were highly predictive of an absence of cardiovascular abnormalities.[31]

Maron et al[32] screened 591 Division 1 college athletes using histories, physical examinations, and electrocardiograms. They identified 90 athletes who required additional evaluation: 24 because of an abnormal physical examination, 13 because of abnormal history, and 65 because of an abnormal electrocardiogram. Upon examination, they found that none of the athletes had serious cardiac disease on echocardiography. The investigators found 15 cases of hemodynamically insignificant mitral valve prolapse and 3 cases of septal thickening without other features of hypertrophic cardiomyopathy.

Electrocardiography did not add diagnostic power and added only to false-positive results. In fact, none of the elements of the examination documented any potentially dangerous lesions.

Because they have low specificity, abnormal electrocardiograms would necessitate a large number of additional and even more expensive tests, such as echocardiography. By increasing the sensitivity of screening, more false-positive results would be anticipated, along with more testing and the associated expense. Such screening would be impractical and costly for schools, especially when considering that cardiovascular deaths occur among high school athletes at an estimated frequency of only 1 in 200,000.[26] If the occurrence of hypertrophic cardiomyopathy in a young athletic population is assumed to be 1 in 500, even at $500 per echocardiogram, it would theoretically cost $250,000 to detect even one previously undiagnosed case.[3]

Currently, the AHA does not recommend routine electrocardiography or echocardiography in preparticipation physical examination screening of athletes. While aware of its limitations, the association recommends the preparticipation physical examination as the most cost-effective strategy for screening athletes for cardiovascular disease.[3]

The risk of sudden cardiac death in high school athletes is about 1 in 72,500

Death of athletes is rare

Van Camp et al[6] studied the frequency and causes of nontraumatic sports deaths in high school and college athletes in the United States through the National Center for Catastrophic Sports Injury Research. From 1983 to 1993, nontraumatic sports deaths were reported in 126 high school athletes and 34 college athletes. Estimated death rates were 7.47 per million male athletes and 1.33 per million female athletes.

Maron et al[33] found a similarly low rate when they examined sudden death due to cardiovascular disease in Minnesota high school athletes. From 1985 to 1997, there were 1,453,280 overall sports participations and 651,695 student participants. There were three sudden cardiac deaths in this group. The calculated risk for sudden cardiac death was 1 per 500,000 participants and 1 per 217,400 participants per academic year. Over the 3-year student athlete high school career, the estimated risk was 1 in 72,500.[33]

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ADDRESS: *Robert J. Dimeff, MD, Department of Sports Medicine, A41, The Cleveland Clinic Foundation, 9500 Euclid Avenue, Cleveland, OH 44195.*