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Preparticipation cardiovascular screening

Craig K. Seto, MD

Department of Family Medicine, University of Virginia Health System, Box 800729, Charlottesville, VA 22908-0729, USA

Promoting physical activity and exercise as a basic health need has become a mission of health care providers and is at the top of our national public health agenda. Benefits derived from exercise and sports participation can be appreciated at all ages [1]. Sports participation can enhance fitness and coordination, increase self esteem, and provide a positive social experience in young athletes [2]. In older individuals, regular aerobic exercise may reduce the risk for fatal and nonfatal myocardial infarction and other coronary events, and has been promoted for both primary and secondary prevention of cardiovascular disease [3]. Despite the many benefits derived from exercise and sports participation, there are medical conditions in young individuals for which participation in sports activity or exercise can be associated with life-threatening complications. In older individuals with underlying heart disease, acute vigorous physical exertion may trigger sudden death or myocardial infarction, particularly in individuals not accustomed to such activity. The incidence of a cardiovascular event during exercise in individuals with cardiac disease is estimated to be 10 times that of otherwise healthy persons. Because of this, adequate screening and evaluation are important to identify and counsel individuals with underlying cardiovascular disease before they begin exercising or participating in sports [3,4]. This article reviews the current preparticipation cardiovascular screening recommendations for individuals of all ages who are contemplating participation in a sport or exercise program.

Cardiovascular screening in young athletes

Approximately 15 million children and adolescents participate in organized sports in the United States. Each year a number of them die suddenly from underlying cardiac abnormalities that are associated with a small subgroup of disorders and high-risk behaviors. Sudden death in the young athlete occurs with

E-mail address: cks2n@virginia.edu

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an estimated prevalence between 1:100,000 and 1:300,000, with death rates approximately five times higher in males than females [5,6]. The most common cardiovascular causes of sudden death in young athletes are due to underlying congenital cardiac anomalies, such as hypertrophic cardiomyopathy (HCM), coronary artery abnormalities, and increased cardiac mass [7]. Although uncommon in competitive sports, sudden death is a catastrophic event, especially when it occurs in an otherwise healthy athlete. Identifying individuals who are at risk for sudden death has been the subject of great study and debate, and this has led to the development of guidelines for preparticipation screening.

In 1996, the American Heart Association (AHA) developed consensus recommendations for cardiovascular screening of student athletes as part of a comprehensive preparticipation physical examination (PPE). In 1997, the Preparticipation Physical Examination monograph was published [2]. The monograph was developed or endorsed by the American Academy of Family Physicians, American Academy of Pediatrics, American College of Cardiology, American College of Sports Medicine, American Heart Association, American Medical Society for Sports Medicine, American Orthopaedic Society for Sports Medicine, and the American Osteopathic Academy of Sports Medicine [7,8]. It incorporates most of the AHA's cardiovascular screening recommendations and was meant to provide practitioners with a standard for performing the preparticipation history and physical examination.

The preparticipation physical examination (PPE)

The overall goal of the PPE is to help maintain the health and safety of the athlete in training and competition. Its purpose is not to exclude athletes from participation, but to promote safe participation. Only 0.3% to 1.3% of athletes are denied clearance during the PPE, and only 3.2% to 13.5% require further evaluation. One of the main objectives of the PPE is to detect conditions that may be life threatening, such as cardiac abnormalities that could predispose an athlete to sudden death [2].

AHA recommendations for the preparticipation examination

Because of the differences in the design and content of preparticipation screening among states, the AHA strongly recommends a national standard for preparticipation medical evaluation, including cardiovascular screening.

General recommendations for preparticipation cardiovascular screening

Screening should be mandatory, and performed on all high school (grades 9–12) and college athletes before participation in organized sports. Screening should be repeated every two years, with an interim history obtained during the intervening years. Screening should include a history and physical examination designed to identify or raise suspicion of cardiovascular lesions known to cause

sudden death or disease progression in young athletes. The screening should be performed by a health care worker (preferably a physician) who has the appropriate training, medical skills and background to reliably obtain a detailed cardiovascular history, perform a thorough physical examination, and recognize heart disease. The AHA contends that the above recommendations are the best and most practical approach to screening competitive sports participants, regardless of age [8,9].

Importance of history in cardiovascular screening:

The personal and family history of the athlete can reveal 64% to 78% of conditions that would prohibit or alter sports participation. It is therefore a more sensitive tool than the physical examination. Specific questions regarding cardiopulmonary disease can help identify whether or not further evaluation and testing will be needed. The following screening questions will help identify significant cardiopulmonary problems in an athlete:

1. Have you ever become dizzy or passed out during or after exercise?
2. Have you ever had chest pain during or after exercise?
3. Do you get tired more quickly than your friends do during exercise?
4. Have you ever had racing of your heart or skipped heartbeats?
5. Have you had high blood pressure or high cholesterol?
6. Have you ever been told that you had a heart murmur?
7. Has any family member or relative died of heart problems or sudden death before age 50?
8. Have you had a severe viral infection such as mononucleosis or myocarditis with in the last month?
9. Has a physician ever denied or restricted your participation in sports for any heart problems [2,10]?
10. Have any of your relatives ever had any of the following conditions?:
    - 10.1. Hypertrophic cardiomyopathy
    - 10.2. Dilated cardiomyopathy
    - 10.3. Marfan's syndrome
    - 10.4. Long QT syndrome
    - 10.5. Significant heart arrhythmia [9]

Young athletes who experience chest pain, syncope, exercise intolerance, or palpitations, or who have a clinically significant family history, will usually not reveal this information unless specifically asked. It is also important that the student athlete and the parent complete the history form together before the physical examination. A recent study demonstrated significant discrepancies between the histories obtained when the parent and the athlete completed the history form separately [11].

Ninety-five percent of sudden deaths in athletes under 30 are due to structural cardiac abnormalities. Several of these conditions (eg, arrhythmias, premature

coronary artery disease, and aberrant coronary arteries) have no auscultatory findings. Paying close attention to the history may be the only way to raise the suspicion for such an underlying condition. HCM, conduction abnormalities, arrhythmias, and valvular abnormalities may produce symptoms of lightheadedness, dizziness, or syncope during or after exercise. Chest pains during or after exercise could indicate a coronary artery anomaly or advanced coronary artery disease. Dyspnea out of proportion to activity could indicate valvular abnormalities or underlying pulmonary disease. Palpitations during or after exercise may indicate an arrhythmia or conduction abnormality. A history of high blood pressure, high cholesterol, recent viral illness (eg, myocarditis or mononucleosis) or prior restriction from participation in sports warrants further investigation. History of a heart murmur should also raise concern, although benign murmurs can be detected on examination of many athletes [2].

A family history of sudden death before age 50 is extremely important, because some causes of death, such as premature coronary artery disease, Marfan's syndrome, long QT syndrome, and HCM, can be familial. Any history that suggests a risk for congenital heart disease should stimulate a more in-depth cardiac evaluation. As a final note, although the history may provide clues to underlying cardiovascular disease, hypertrophic cardiomyopathy, the most common cause of death in young athletes, may not produce any symptoms before sudden death [10].

Medication and drug use history

A large number of prescription medications, over-the-counter preparations, and illegal drugs may have significant cardiovascular effects in the athlete population. The history should include an assessment of the use of current medications, supplements, illicit drugs, alcohol, and tobacco. Prescription medications such as beta agonists, theophylline, tricyclic antidepressants, macrolide antibiotics, and nonprescription drugs such as decongestants (pseudoephedrine and phenylpropanolamine) have been linked to arrhythmias. Cocaine, amphetamines, ephedrine, and anabolic steroids have known cardiotoxic effects and have been linked to sudden death. A candid discussion regarding drug and medication use and its consequences should be undertaken as part of the cardiovascular screening history [10,12,13].

The cardiovascular examination

The standard components of the cardiovascular screening examination include measurement of blood pressure, palpation of radial and femoral pulses, and a cardiac examination, to include rate, rhythm, and presence and characterization of any murmur or abnormal heart sounds. The AHA also recommends that examiners be able to recognize the physical manifestations of Marfan's syndrome.

Evaluation of blood pressure

The brachial blood pressure should be measured in the seated position with an appropriate size cuff. If the blood pressure remains elevated after resting 10 to

15 minutes, the individual should be questioned about the use of stimulants such as caffeine, nicotine, decongestants, or methylphenadate (Ritalin). The condition should then be referred to the primary care physician for further evaluation.

Pulse

Palpation of the radial and femoral pulses will determine whether the heart rate and rhythm are regular. A weak or nonpalpable femoral artery pulse suggests coarctation of the aorta.

Recognition of Marfan's syndrome

Examiners should be able to recognize the stigmata of Marfan's syndrome, which include:

Tall stature and arm span greater than height
High-arched palate
Pectus excavatum, arachnodactyly, kyphoscoliosis.
Heart murmur associated with mitral valve prolapse or aortic regurgitation.
Myopia or ectopic lens.

Marfan's syndrome should be suspected in an athlete who is tall, has long fingers and toes, has pectus excavatum chest wall deformity, and a high arched palate [8,14].

The cardiac examination

Precordial auscultation of the heart should be performed in the supine and standing positions to identify murmurs consistent with dynamic left ventricular outflow obstruction. Standing is preferred to sitting, because the murmur of hypertrophic cardiomyopathy tends to be louder when the patient is standing. Particular attention should be paid to the presence and character of any clicks, murmurs, and the presence of other heart sounds such as S3 and S4.

Maneuvers such as a squat-to-stand, deep inspiration, or a Valsalva maneuver can help clarify the type of murmur. Squatting will increase venous return to the heart, which in turn increases left ventricular blood volume, stroke volume, and systemic vascular resistance. Returning to a standing position reverses these changes. A Valsalva maneuver decreases venous return to the heart, and thereby has the opposite effect of squatting.

Mitral valve prolapse typically produces a mid-systolic click and sometimes a late-systolic murmur. Hypertrophic cardiomyopathy typically produces a murmur that increases in intensity with standing and with a Valsalva maneuver. These maneuvers decrease venous return to the heart and will accentuate the obstruction to flow around the pathologically enlarged interventricular septum or ventricular wall, thus creating an intensification of the murmur. Squatting, on the other hand, increases venous return to the heart and thereby decreases the murmur of HCM.

Aortic stenosis produces a harsh systolic murmur that increases with squatting and decreases with a Valsalva maneuver. Innocent or functional murmurs also

increase with squatting and decrease with the Valsalva maneuver, but an innocent murmur is typically less than 3/6 in intensity, has no diastolic component, and is associated with a normal physiologic split of the second heart sound.

Abnormal murmurs have the following characteristics:

1. Any murmur grade 3/6 or more
2. Any diastolic murmur
3. Any murmur that gets louder with Valsalva maneuver

Murmurs with any of the above characteristics should be further evaluated before an athlete is cleared to play [2]. If there is any uncertainty about the nature of a murmur or any cardiac symptoms noted in the history, referral to a cardiologist for evaluation is recommended. Also, it must be remembered that the physical examination and auscultation alone cannot detect all cases or types of heart disease [22,24].

Summary of cardiovascular history and physical examination

The focused cardiovascular examination should seek to rule out historical or physical examination features that have been associated with common causes of sudden death in young athletes. When a cardiovascular abnormality is identified or suspected, the athlete should be referred to a cardiovascular specialist for further evaluation and confirmation. Further evaluation may include electrocardiography, echocardiography, exercise stress testing, or cardiac catheterization. The athlete will require temporary disqualification from athletic participation until the evaluation is complete [2,22]. Once a cardiovascular abnormality has been definitively identified, the eligibility for future athletic competition should be based upon the recommendations of the 26th Bethesda Conference Consensus Panel [15].

Young women are less likely to experience sudden death on the athletic field, and account for only about 15% of such deaths. Nevertheless, the AHA does not recommend any gender specific cardiovascular alteration in the screening of female athletes.

Noninvasive cardiovascular screening

Electrocardiograph (ECG) screening

Use of the 12-lead ECG for the screening of high school and collegiate athletes has been studied and found not to be cost effective. It is currently not recommended by the AHA or other organizations for routine screening of asymptomatic athletes. In normal, well-conditioned young athletes, the heart may develop ECG changes that falsely suggest ventricular hypertrophy; thus the specificity of the ECG is low in this population [9,16]. Nevertheless, selective use

of ECG can be useful in assessing young athletes who, on the basis of personal history, family history, or physical examination, are thought to be at potentially higher risk. The resting ECG is abnormal in 80% to 90% of patients with hypertrophic cardiomyopathy (HCM), coronary anomalies, right ventricular dysplasias, and long QT interval syndrome. The most common ECG abnormalities in athletes with these conditions are voltage criteria for left ventricular hypertrophy, abnormal ST segments, T-wave inversion, and deep Q waves [9,17].

Screening echocardiography

Several studies have applied echocardiography to screening large athletic populations. The results of these studies demonstrate that echocardiography has limited use in screening asymptomatic athletic populations, due to the high cost and the low prevalence of disease. Problems with false-positive results (increases in left ventricular wall thickness that occur as a normal physiologic adaptation in the athlete) and false negative results (hypertrophic cardiomyopathy may not demonstrate septal thickening until the end of adolescence) can occur. The main concerns with echocardiography are the high cost and the risk of misdiagnosing a healthy athletic heart and therefore restricting an otherwise healthy athlete. However, 2-Dimensional echocardiography remains the diagnostic study of choice for the detection of HCM when the history and physical examination raise suspicion of this disorder. Echocardiograms can identify valvular pathology and demonstrate left ventricular anatomic changes and dysfunction, aortic root dilatation, and possibly aberrant origins of the left main coronary artery [9,17,23].

Exercise stress testing recommendations

Exercise testing has not been shown to be cost effective and is not recommended for the mass screening of young athletes. It is appropriate in the older athlete with known coronary artery disease, or when symptoms suggest stable angina or exercise-induced anginal variants. Exercise stress testing is also appropriate when risk factors (hypertension, smoking, or diabetes mellitus) are present, and the patient is contemplating an increase in exercise intensity. The American College of Sports Medicine recommends exercise stress testing in men older than 40 and women older than 50 before starting a vigorous exercise program [3,12].

Summary of noninvasive testing

Noninvasive testing (eg, echocardiography and electrocardiography) can enhance the diagnostic power of the standard history and physical examination, but it is not recommended for cardiovascular PPE screening. Comprehensive and expensive screening tests have not proved to be cost effective, nor can they consistently identify athletes at risk. The widespread use of noninvasive testing in athletic populations is impractical and could result in many false-positive test results that would greatly exceed the number of true-positive results. This is due

to the large number of competitive athletes in the United States, the relatively low frequency of cardiovascular lesions responsible for deaths, and the low rate of sudden cardiac death in young athletes [7,9].

The cost effectiveness of cardiovascular screening

The low yield of clinically significant cardiac abnormalities from screening has generated debate about the usefulness of the cardiac portion of the sports PPE. The practicality and utility of screening are limited by the low prevalence of relevant cardiovascular lesions in the general youth population, the low risk of sudden death even among persons with an unsuspected abnormality, and the large size of the competitive athletic population.

Currently, there is no cost-effective battery of tests to identify all, or even most, of the dangerous cardiovascular conditions in young athletes. Various screening methods for sudden cardiac death have been investigated, but no clear-cut, cost-effective method has emerged. It has been estimated that 200,000 children and adolescents would have to be screened to detect 1000 athletes who are at risk for sudden death and one person who would actually die [7,10,18]. Despite a lack of compelling evidence to show that cardiovascular PPE screening is effective, it is recommended based on cost and medicolegal considerations. Although this method may be imperfect, the AHA panel considers it the most practical and best available strategy for screening large populations of athletes. Additionally, many physicians use the PPE as a venue to investigate and address other adolescent health issues in a population that is rarely seen for routine medical care otherwise [7,9].

Implementation of AHA cardiovascular screening recommendations

Currently in the United States, there are no uniformly accepted standards for conducting sports PPEs or certifying health professionals who perform these examinations. Decisions on PPE content are often made locally by school districts and even individual schools, resulting in significant variation in the manner in which PPEs are conducted. Although states that designate specific examiners recommend that physicians be responsible for preparticipation screening, 12 states allow nurses or physician assistants to conduct PPEs, and 11 states allow chiropractors to provide athletic clearance.

A recent survey regarding PPE policies by state demonstrated significant differences and inconsistent use of the AHA recommendations for cardiovascular screening. In 1998, 40 percent of US states were inadequately screening high school athletes for sudden cardiac death, based upon the AHA recommendations. A survey of state high school athletic associations in the 50 states and Washington, DC revealed that 8 states did not offer an approved history and physical examination questionnaire to help guide PPE examiners. One state (Rhode Island)

had no preparticipation screening requirement. Despite the availability and medical endorsement of a standard PPE form, a nationwide survey of 254 high schools revealed that only 17% used forms that contained all the elements of the cardiac history recommended for identifying athletes at risk for sudden death [7,19]. A similar trend was found in higher education. A survey of 879 National Collegiate Athletic Association colleges and universities found that PPE screening was required by 855 schools (97%); however, only 163 (26%) incorporated most of the 1996 AHA recommendations for cardiovascular PPE screening [20]. It is clear from the results of these studies that the adoption of a national standard for PPEs that incorporates the AHA's recommendations would improve the quality and uniformity of cardiovascular screening provided to young athletes.

Cardiovascular screening at health and fitness facilities

In 1998, the AHA and American College of Sports Medicine (ACSM) published a joint statement of recommendations for cardiovascular screening at health and fitness facilities [4]. The statement provides recommendations for cardiovascular screening of all persons before enrollment or participation in activities at such facilities. Staff qualification and emergency policies related to cardiovascular safety are also discussed. The primary purpose of the preparticipation screening is to identify those individuals not known to be at risk for an exercise-related cardiovascular event and to risk-stratify those with established cardiovascular risks. The screening is designed to identify persons at high risk and is simple and easy to perform.

The joint statement recommends the use of a self-administered questionnaire to be given to participants when they register at a health and fitness facility. The Physical Activity Readiness Questionnaire (PAR-Q) is a screening tool that focuses primarily on symptoms that might suggest angina pectoris. It also identifies musculoskeletal problems that should be evaluated before participation.

The PAR-Q includes the following questions:

1. Has a doctor ever said that you have a heart condition and recommended only medically supervised activity?
2. Do you have chest pain brought on by physical activity?
3. Have you developed chest pain in the past month?
4. Have you on one or more occasions lost consciousness or fallen over as a result of dizziness?
5. Do you have a bone or joint problems that could be aggravated by the proposed physical activity?
6. Has a doctor ever recommended medication for your blood pressure or heart condition?
7. Are you aware, through your own experience or a doctor's advice, of any other physical reason that would prohibit you from exercising without medical supervision?

Participants are directed to contact their personal physician if they answer "yes" to any of the questions. The AHA and ACSM recommends using the PAR-Q or a slightly more complex questionnaire (AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire) for the preparticipation screening of all individuals at health and fitness clubs before their participation [21].

Screening for masters athletes

In 2000, the AHA published recommendations for the preparticipation medical evaluation before entry into a masters sports training program. Masters sports are organized forms of competition specifically designed for older athletes. The participants are predominantly male, and have a wide age range, but typically are older than 35, with many being older than 40 or 50. Although masters sports programs are primarily comprised of apparently healthy individuals from the general population, some masters athletes compete with known, documented cardiovascular disease. The most common form of heart disease in this population is coronary heart disease.

The prevalence of sudden death during organized masters competition or training is not precisely known. Studies of adult athletes such as joggers and marathon runners can provide an estimate. Data from these studies have shown a risk of sudden death of 1:15,000 in joggers per year to 1:50,000 participants in marathons. Other observations suggest that sudden death and cardiac events are not rare in the older athletic population.

Major objectives of the screening process are to identify or raise suspicion of underlying cardiovascular disease that has the potential of producing sudden death or other nonfatal cardiac events. In athletes with known cardiovascular disease, the screening evaluation will help determine whether sports participation is judicious, based on the severity of their disease. A cardiac evaluation should also be repeated any time there are new signs or symptoms consistent with cardiovascular disease. Finally, in this population of athletes, lack of symptoms does not ensure the absence of cardiovascular disease, and thus periodic examinations are prudent.

Specific recommendations for screening include:

The history should include a detailed family history of sudden death or heart disease in surviving relatives. A personal history of a heart murmur, hypertension, fatigability, syncope, exertional dyspnea, or exertional chest pain should be obtained.

The physical examination should focus on blood pressure measurement, the presence of a heart murmur, palpation of femoral pulses, and looking for stigmata of Marfan's syndrome.

Exercise testing is recommended for masters athletes who have a moderate to high cardiovascular risk profile for coronary heart disease. This risk profile includes men >40 years of age and women >50 years of age (or postmenopausal) with one or more independent coronary-risk factors. Risk factors include:

hypercholesterolemia or dyslipidemia, systemic hypertension, current or recent cigarette smoking, diabetes mellitus, or a history of myocardial infarction or sudden death in a first degree relative < 60 years old.

Exercise stress testing is also recommended for masters athletes of any age with symptoms suggestive of coronary artery disease, as well as individuals 65 years or older even without risk factors or symptoms. A positive test requires further evaluation to establish the presence and severity of coronary artery disease.

The standard 12-lead ECG is recommended as part of the routine screening evaluation of all masters athletes (male and female) over the age of 40. Although the ECG is of limited diagnostic value for detecting coronary artery disease in the asymptomatic masters population, it may occasionally identify evidence of a prior myocardial infarction. It can also be helpful in detecting certain diseases that are less common in the older population, such as hypertrophic cardiomyopathy, long QT syndrome, Brugada syndrome, Wolff-Parkinson-White pre-excitation syndrome, and arrhythmogenic right ventricular dysplasia.

Diagnostic echocardiography is not recommended for general screening, but is indicated when clinical, historical, or physical findings suggest the possibility of structural heart disease or previous myocardial infarction.

There are conflicting data regarding the recommendations for screening asymptomatic patients, particularly men over 50 who are about to begin a low-intensity exercise program. Those individuals who are perceived to be at higher risk for coronary artery disease should be screened with an exercise stress test, however [3].

Summary

Regular aerobic exercise provides many health benefits regardless of age, and should be promoted by health care providers to all patients. In older athletes, coronary artery disease is the most common cause of sudden death. There is widespread consensus, however, that the overall health benefits derived from exercise outweigh the risks of participation. Screening should focus on identifying signs and symptoms of underlying cardiovascular disease by obtaining a personal and family history and performing a focused physical examination according to the recommendations of the AHA. Exercise testing is recommended in males older than 40 and females older than 50, and individuals with cardiac risk factors.

Cardiovascular PPE screening in young athletes remains a challenge, because potentially fatal abnormalities are uncommon and in some cases are undetectable without sophisticated testing. Most sudden cardiac deaths in athletes are caused by anomalies that are clinically silent, are rare, or are difficult to detect by history and physical examination. Many athletes may not experience symptoms consistent with heart disease or may not report family histories of sudden cardiac death. Important clues to a cardiac abnormality include history of syncope, chest pain, and family history of sudden death. Any underlying condition suspected on the

basis of history or physical examination requires further diagnostic evaluation before the athlete can be cleared for activity.

Currently there is considerable variability and inconsistency among state requirements for PPEs. A national adoption of a more uniform PPE screening process should be encouraged. The screening process should include the AHA's cardiovascular screening recommendations, as this would assist in closing the gap between screening practices recommended by sports medicine experts and the reality of current screening practices. Although the extent of screening continues to be debated, clinical guidelines for performing PPEs and determining clearance have been established. Without a uniform implementation of the current guidelines, it will not be possible to assess the value of the current cardiovascular screening recommendations in detecting and preventing cardiovascular death in young athletes.

Physicians should be aware of the emerging role of genetic testing for cardiovascular diseases in athletes with a family history of heart disease or sudden death. Advances in the diagnosis and understanding of cardiovascular disease may provide better tools for preventing sudden death of young athletes in the future [11].

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