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Recommendations and Considerations Related to Preparticipation Screening for Cardiovascular Abnormalities in Competitive Athletes: 2007 Update

A Scientific Statement From the American Heart Association Council on Nutrition, Physical Activity, and Metabolism

Endorsed by the American College of Cardiology Foundation

Barry J. Maron, MD, Chair; Paul D. Thompson, MD, FAHA, Co-Chair;
Michael J. Ackerman, MD, PhD; Gary Balady, MD, FAHA; Stuart Berger, MD; David Cohen, MD;
Robert Dimeff, MD; Pamela S. Douglas, MD, FAHA; David W. Glover, MD;
Adolph M. Hutter, Jr, MD, FAHA; Michael D. Krauss, MD; Martin S. Maron, MD;
Matthew J. Mitten, JD; William O. Roberts, MD; James C. Puffer, MD

Sudden deaths of young competitive athletes are tragic events that continue to have a considerable impact on the lay and medical communities.¹⁻¹⁷ These deaths are usually due to a variety of unsuspected cardiovascular diseases and have been reported with increasing frequency in both the United States and Europe.^{1,5} Such deaths often assume a high public profile because of the youth of the victims and the generally held perception that trained athletes constitute the healthiest segment of society, with the deaths of well-known elite athletes often exaggerating this visibility. These counterintuitive events strike to the core of our sensibilities, periodically galvanizing discussion and action, and in the process raise practical and ethical issues related to detection of the responsible cardiovascular conditions.

Preparticipation cardiovascular screening is the systematic practice of medically evaluating large, general populations of athletes before participation in sports for the purpose of identifying (or raising suspicion of) abnormalities that could provoke disease progression or sudden death.^{13,16} Indeed, identification of the relevant diseases may well prevent some instances of sudden death after temporary or permanent withdrawal from sports or targeted treatment interventions.^{15,17-21} In addition, the increasing awareness that automated external defibrillators (AEDs) may not always prove successful in the secondary prevention of sudden death for

athletes with cardiovascular disease²² underscores the importance of preparticipation screening for the prospective identification of at-risk athletes and the prophylactic prevention of cardiac events during sports by selective disqualification.

Although some critics have questioned the effectiveness of cardiovascular screening,^{23,24} overwhelming support for the principle of this public health initiative exists in both the medical and lay communities.^{13-16,25} The efficacy of the various athlete screening strategies is not easily resolved in the context of evidence-based investigative medicine.

Recently, recommendations of the European Society of Cardiology (ESC)¹⁶ and International Olympic Committee (IOC)^{26,27} have triggered a new debate regarding the most appropriate strategy for screening trained athletes and other sports participants. Indeed, issues related to the methodology and justification for preparticipation screening, including use of the 12-lead electrocardiogram (ECG), have become a complex area of debate.

The present document is largely a response to these recent considerations and developments and represents the consensus of a number of cardiovascular and other specialists with extensive clinical experience and expertise related to athletes of all ages, as well as a sports medicine legal expert. The panel addressed the benefits and limitations of the screening process for early detection of cardiovascular abnormalities in

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competitive athletes, cost-effectiveness, feasibility issues, and relevant medical-legal implications. The results of these deliberations constitute the consensus recommendations and guidelines presented here, which we believe outline the most prudent, practical, and effective screening strategies for competitive athletes in the United States. This update of the 1996 American Heart Association (AHA) preparticipation screening scientific statement¹³ 10 years later seems particularly relevant and timely given the large number of competitive athletes in this country; the continuing (if not accelerating) interest in the problem of athletic field deaths; recent public health initiatives on physical activity, exercise, and screening; and the rapidly approaching 2008 Beijing Olympic Games.

Definitions and Background

The present discussion focuses on the competitive athlete, defined as one who participates in an organized team or individual sport that requires systematic training and regular competition against others and places a high premium on athletic excellence and achievement. This definition includes organized and sanctioned sports (interscholastic: middle school and high school), college sports (intercollegiate and club sports, but exclusive of intramural competition), and professional sports, which are examined separately.

The purpose of preparticipation screening (as described here) is to provide potential participants with a determination of medical eligibility for competitive sports that is based on evaluations intended to identify (or raise suspicion of) clinically relevant, preexisting abnormalities. Although this screening process traditionally involves the evaluation of many organ systems, the focus here is on cardiovascular disease. The principal objective of screening is to reduce the cardiovascular risks associated with organized sports and enhance the safety of athletic participation; however, raising the suspicion of a cardiac abnormality on a standard screening examination is only the first tier of recognition, after which subspecialty referral for further diagnostic testing is generally necessary.

When a definitive diagnosis of heart disease is made, the consensus panel guidelines of Bethesda Conference No. 36^{15,20,28} may be used to formulate recommendations for either continued participation or disqualification (temporary or permanent) from competitive athletics. For those young athletes with genetic heart disease who are disqualified from competitive sports, recommendations for recreational athletic activities and normal lifestyle are available.²⁹

The guidelines advanced in the present document focus primarily on the mass screening of high school and collegiate student-athletes of all races and both genders. However, these recommendations may also apply to athletes in youth (≤ 12 years of age) or masters (≥ 30 years of age) sports,³⁰ as well as to clinical assessments in other venues, such as individuals or small groups of athletes evaluated primarily in office practice settings by personal or team physicians. Preparticipation screening of a single athlete (or small groups) by personal physicians also requires a standard history and physical examination but may be much more likely to include noninvasive testing. A limitation attached to medical evalu-

ations performed only for athlete screening purposes is the lack of insurance carrier reimbursements for such examinations. It is also understood that the standard preparticipation screening examination extends beyond considerations for cardiovascular disease and involves numerous other medical issues and organ systems.

The present AHA recommendations and the importance attributed to screening are predicated on the likelihood that intense athletic training and competition act as a trigger to increase the risk for sudden cardiac death or disease progression in susceptible athletes with underlying heart disease (although quantification of that risk remains elusive).^{1,6,8,9,16} Indeed, the vast majority of young athletes who die suddenly of cardiovascular disease do so during sports training or competition, and a relationship has been drawn between intense physical activity and arrhythmia-based sudden death.^{1,6,8,16} This risk of sudden death, however, appears to be independent of the level of athletic competition (ie, high school, college, or professional). Finally, early detection of clinically significant cardiovascular disease through preparticipation screening^{13,16} will, in some cases, permit timely therapeutic interventions that may alter clinical course and significantly prolong life.^{18,19} For example, high-risk individuals with genetic heart disease may be eligible for prophylactic implantable cardioverter-defibrillators or other therapeutic interventions.³¹

Causes of Sudden Death in Athletes

A variety of cardiovascular diseases represent the most common causes of sudden death in young athletes.^{1,4,6,8} The vast majority of these deaths in US athletes < 35 years of age are due to several congenital or acquired cardiac malformations (see the Figure). Hypertrophic cardiomyopathy (HCM)³² is the single most common cause of athlete deaths (responsible for approximately one third of the cases), followed by congenital coronary artery anomalies, particularly those of wrong aortic sinus origin.¹¹ Several other cardiovascular diseases account for $\approx 5\%$ or less of these deaths in athletes. In the United States, these deaths occur most commonly in basketball and football, sports that have the highest levels of participation and also involve particularly intense levels of physical activity.^{1,4,6}

The older athlete population (more than approximately 35 to 40 years of age) presents a different demographic profile, with participation commonly in individual sports such as long-distance and road racing (including the marathon).^{33,34} The vast majority of deaths in middle-aged athletes are due to unsuspected atherosclerotic coronary artery disease.^{33,34}

Because this document focuses on the cardiovascular evaluation of athletes, other related medical problems that may also cause sudden death in such individuals are not considered here. These conditions include heat stroke, cerebral aneurysm, bronchial asthma, nonpenetrating blunt chest blows (commotio cordis),³⁵ and sickle-cell trait, as well as nutritional supplements and illicit drugs.

Prevalence and Scope of the Problem

Relevant to the design of any screening strategy is the fact that sudden cardiac death in athletes is an infrequent event

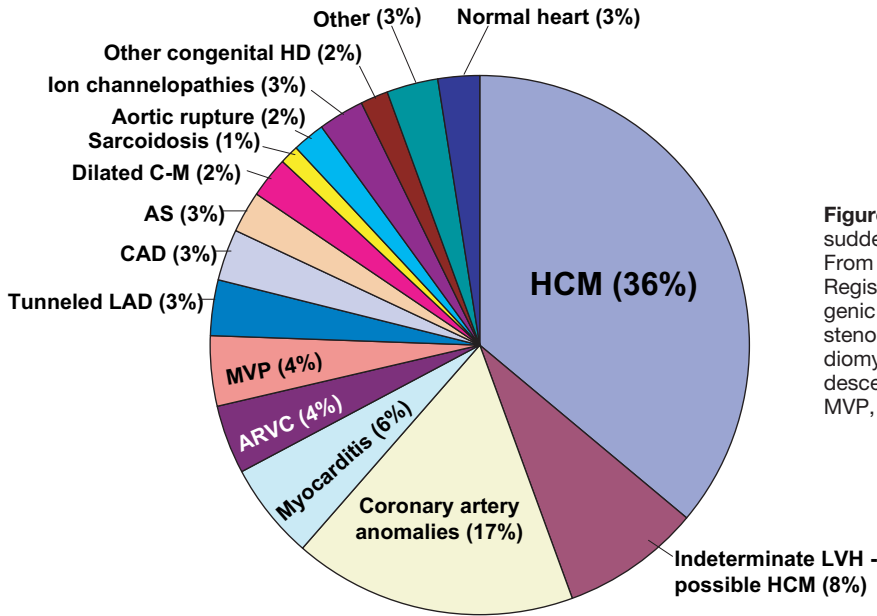


Figure. Distribution of cardiovascular causes of sudden death in 1435 young competitive athletes. From the Minneapolis Heart Institute Foundation Registry, 1980 to 2005. ARVC indicates arrhythmogenic right ventricular cardiomyopathy; AS, aortic stenosis; CAD, coronary artery disease; C-M, cardiomyopathy; HD, heart disease; LAD, left anterior descending; LVH, left ventricular hypertrophy; and MVP, mitral valve prolapse.

and that only a small proportion of those participating in organized sports are in fact at risk because of unsuspected cardiovascular disease. Indeed, each of the conditions known to be responsible for sudden death in young athletes occurs infrequently in the general population, ranging from the relatively common HCM (1:500)³⁶ to much rarer conditions, such as congenital coronary artery anomalies, arrhythmogenic right ventricular dysplasia, ion channelopathies (long-QT syndrome, catecholaminergic polymorphic ventricular tachycardia, and Brugada syndrome), and Marfan syndrome. The cardiac diseases relevant to these screening considerations probably account for an estimated combined prevalence of 0.3% in general athlete populations.

In addition, the large reservoir of competitive athletes in the United States constitutes a major obstacle to systematic screening strategies. Each year, there are probably more than 5 million individual competitive athletes at the high school level (grades 9 to 12), in addition to lesser numbers of collegiate (including the NCAA [National Collegiate Athletic Association], NAIA [National Association of Intercollegiate Athletics], and junior colleges; >500 000), and professional (≈5000) athletes. This does not take into consideration the many youth, middle school, and masters-level competitors for whom reliable numbers are not available. Therefore, depending on the precise definition used, the relevant athlete population available for screening may be as large as 10 million persons annually.

Although the incidence of athlete deaths is not known with certainty, it would appear to be in the range of 1:200 000 young people of high school age per year, according to a Minnesota study of 1.4 million student-athlete participants in 27 sports over a 12-year period.¹⁰ Although the frequency of deaths in young athletes appears to be relatively low, such deaths are undoubtedly more common than previously thought and represent a substantive public health problem.

Ethical Considerations

There is general consensus that in a benevolent society, a responsibility exists on the part of physicians to initiate

prudent efforts to identify life-threatening conditions in athletes for the purpose of minimizing the risk associated with the intersection of sports and cardiovascular disease. Specifically, there would also appear to be an implicit ethical (and possibly legal) obligation on the part of educational institutions (eg, high schools and colleges) to implement cost-effective strategies to ensure that student-athletes are not subjected to unacceptable and avoidable medical risks that could lead to injury or death.

The extent to which preparticipation screening efforts can be supported is, however, mitigated by the recognition that it is not possible to achieve a “zero-risk” circumstance in competitive sports. Indeed, selectively, there is an implied acceptance of small inherent risks of injury on the part of participants. For example, as a society, we condone many athletic activities with known intrinsic risks that cannot be controlled in absolute terms, eg, automobile racing or mountain climbing, as well as more traditional sports such as football and boxing, in which the possibility of serious traumatic injury is recognized as an implicit aspect of participation.

AHA Screening Guidelines

The present 2007 AHA recommendations for personal and family history and physical examination are promoted by the panel as a potentially effective strategy to raise the suspicion of cardiovascular disease in both large and small screening populations of high school and college student-athletes (see the Table). These recommendations were initially proposed in the 1996 AHA Scientific Statement¹³ and appear here virtually unaltered (Table). The 2007 AHA recommendations consist of 12 items (8 for personal and family history and 4 for physical examination). At the discretion of the examiner, a positive response or finding in any 1 or more of the 12 items may be judged sufficient to trigger a referral for cardiovascular evaluation. Parental verification of the responses is regarded as essential for high school (and middle school) students.

TABLE. The 12-Element AHA Recommendations for Preparticipation Cardiovascular Screening of Competitive Athletes

Medical history*	
Personal history	
1.	Exertional chest pain/discomfort
2.	Unexplained syncope/near-syncope†
3.	Excessive exertional and unexplained dyspnea/fatigue, associated with exercise
4.	Prior recognition of a heart murmur
5.	Elevated systemic blood pressure
Family history	
6.	Premature death (sudden and unexpected, or otherwise) before age 50 years due to heart disease, in ≥1 relative
7.	Disability from heart disease in a close relative <50 years of age
8.	Specific knowledge of certain cardiac conditions in family members: hypertrophic or dilated cardiomyopathy, long-QT syndrome or other ion channelopathies, Marfan syndrome, or clinically important arrhythmias
Physical examination	
9.	Heart murmur‡
10.	Femoral pulses to exclude aortic coarctation
11.	Physical stigmata of Marfan syndrome
12.	Brachial artery blood pressure (sitting position)§

*Parental verification is recommended for high school and middle school athletes.

†Judged not to be neurocardiogenic (vasovagal); of particular concern when related to exertion.

‡Auscultation should be performed in both supine and standing positions (or with Valsalva maneuver), specifically to identify murmurs of dynamic left ventricular outflow tract obstruction.

§Preferably taken in both arms.³⁷

Medical-Legal Considerations

There currently is no uniform body of law in the United States that clearly defines the legal duties of sports governing bodies and educational institutions with regard to the mass preparticipation screening of competitive athletes. Furthermore, no federal or state statutes in the United States establish the precise nature and scope of preparticipation cardiovascular screening in competitive athletes. In contrast to US law, Italian law both mandates the required scope of cardiovascular screening and holds physicians criminally negligent for improperly clearing an athlete with an undetected cardiovascular abnormality that ultimately leads to death during sports.³⁸

Given the absence of specific legal requirements and a lack of medical expertise sufficient to establish appropriate standards, most college (and professional) sports teams rely on their respective team physicians to determine appropriate medical screening procedures. High schools generally rely on each individual athlete's personal physician to do so (or on other physicians who volunteer or are asked to perform preparticipation medical evaluations of team members). Customary screening practice for both US high school and college athletes has consisted of personal and family history-taking and physical examination.

Although state laws vary, the law generally requires that individual physicians use reasonable care in detecting foreseeable medical abnormalities that may cause sudden death or serious injury to athletes participating in organized competitive sports.³⁹ The law permits the medical profession to establish the appropriate scope of athlete preparticipation screening on the basis of its members' collective medical judgment. For example, the law recognizes that physicians are in the best position to evaluate the relevant medical, economic, and feasibility factors and to develop reliable strategies and protocols for identifying cardiovascular abnormalities in athletes.

Physicians who provide medical eligibility clearance and allow participation in competitive sports are not legally liable per se for an injury or death caused by an undiscovered cardiovascular abnormality. Malpractice liability for failure to discover latent, asymptomatic cardiovascular disease requires proof that the physician deviated from customary or accepted medical practice in his or her specialty while performing screening and furthermore that proper utilization of appropriate diagnostic criteria would likely have disclosed the underlying medical condition before injury or death occurred.

Medicine and the law have the same objectives of ensuring that consistent, reliable, and cost-effective clinical procedures are used to evaluate an individual's medical fitness to participate in competitive sports. Similar to the 1996 AHA screening recommendations,¹³ the 2007 AHA recommendations are based on a careful analysis of the relevant medical and economic factors (as well as practical considerations) by an experienced group of American medical experts (Table).

To date, no litigation in American courts has established definitive judicial precedent (ie, judge-made case law) with regard to the legal effect of compliance or noncompliance with the 1996 AHA screening guidelines. Thus, like the 1996 guidelines, the legal effect of the 2007 AHA screening guidelines is uncertain and will vary by jurisdiction. In some states, the guidelines may constitute some evidence of the medical standard of care for mass screening of athletes. In other states, compliance with these guidelines may establish a presumption (ie, rebuttable) that a physician has met the appropriate legal standard of care. In most states, however, the legal consequence of failure to comply with AHA screening guidelines remains unclear.⁴⁰

Nevertheless, despite uncertain legal effects, it is prudent for physicians to follow the updated 2007 AHA recommendations when conducting large-scale preparticipation screening of athletes (Table). Courts have recognized that it is appropriate for physicians to follow current consensus guidelines in determining an athlete's cardiovascular fitness to participate in competitive sports, thereby suggesting that following the guidelines is evidence of good medical practice.^{41,42} Providing the minimum level of screening recommended by the 2007 AHA guidelines, in most cases, likely constitutes some evidence of physician compliance with the medical standard of care and may provide the basis for a successful defense against alleged malpractice. Conversely, lack of compliance with these recommendations may result in medical malpractice liability for an athlete's death or injury

caused by a cardiovascular abnormality that probably would have been discovered if these guidelines had been followed.⁴³

Although the Switzerland-based IOC and the ESC have advocated that all young competitive athletes be screened routinely with a 12-lead ECG (in addition to history-taking and physical examination), the updated 2007 AHA guidelines do not make this recommendation. No federal or state laws currently mandate that American physicians adopt the ESC¹⁶ and IOC^{26,27} guidelines. American law permits US medical organizations and physicians to assess independently the relevant variables (including the current infeasibility of routinely performing ECGs on populations of asymptomatic US athletes) and to make their own recommendations about the appropriate nature and scope of cardiovascular screening. Thus, a US physician's decision to follow the updated AHA recommendations rather than those of the ESC and IOC does not itself constitute medical malpractice.

Finally, athletes (whether or not minors) have an implicit duty to use reasonable care to protect their health and safety as part of the preparticipation screening process. Hence, athletes are required to be truthful in providing their medical history, with accurate responses to the historical questions and any other material information that may be pertinent to their health.

Clinical Implications of the Medical-Legal Considerations

There have been relatively few lawsuits brought against physicians that allege negligent preparticipation screening of athletes, and virtually all of these lawsuits have been settled before resolution by courts.⁴⁴ Thus, a comprehensive medical-legal framework governing preparticipation screening has not yet evolved. Nevertheless, these cases illustrate the need for physicians to take effective steps to minimize potential legal liability related to screening.⁴⁴ Indeed, one strategy by which physicians can limit liability is to follow the 2007 AHA recommendations for personal and family history and physical examination screening. Also, medical clearance for sports should be completed before an athlete is allowed to participate in practice sessions; if subspecialty evaluation is being considered, the athlete should not be permitted to practice or compete in events until final medical clearance is given.

In legal terms, it is important to emphasize that the precise nature and scope of the physician-patient (athlete) relationship during standard preparticipation screening is unresolved. It is advisable for physicians performing preparticipation screening to prospectively define the scope of their relationship with the athlete (as a patient), which will clarify expectations to limit their liability and risk for medical malpractice. This strategy would require consultation with an attorney to develop an appropriate document that defines the scope and limits of the legal relationship between the physician and athlete.

The liability risks associated with sports eligibility clearance by screening are of particular concern among primary care physicians (eg, family physicians, pediatricians, and internists), as well as among nonphysician healthcare professionals, who perform screening medical examinations on high

school athletes. Major considerations include difficulties in differentiating common innocent heart murmurs from uncommon pathological murmurs, detecting or reliably raising the clinical suspicion of potentially lethal cardiovascular conditions that may fall beyond their medical expertise, and discerning which athletes are most deserving of further expensive diagnostic testing and consultations with subspecialists.

For the AHA to officially adopt (or even condone) the ESC screening recommendation for routine ECGs without a reasonable expectation that such a program could be implemented in the near future could have a paradoxical, chilling effect on US preparticipation screening. Practitioners involved with screening would be potentially compromised by being unable to comply with the proposed screening strategy incorporating an ECG. Therefore, it is possible that the willingness of qualified US physicians to participate in screening would be reduced if the ESC/IOC recommendations were mandated.

Finally, the panel makes no basic distinction with regard to customary practice between mass preparticipation screening in a school environment and evaluations conducted in a physician's office setting in only one (or a few) athlete(s). For example, even in a medical environment in which testing is more accessible, a physician would not be obligated to introduce 12-lead ECGs or echocardiograms into the evaluation if not dictated by the findings on history or physical examination.

Current Customary Practices

High Schools

There are no universally accepted or mandated standards for the screening of high school (and college) athletes, nor are there approved certification guidelines for those healthcare professionals who perform such screening examinations. Some form of medical clearance by a physician or other trained healthcare worker, usually consisting of a history and physical examination, is customary. The responsibility for obtaining medical clearance usually rests with the individual high school student-athlete to identify a healthcare provider for the purpose of obtaining medical clearance for sports. For high school athletes, standards have been established by the state legislatures or recommended by the individual state high school athletic association, local school districts, or, in some cases, the state Department of Education. The National Federation of State High Schools has not played a primary regulatory role in the design, performance, and quality control of the high school screening process but has preferred to leave this authority to each individual state association.

In 1997, the level of sophistication present in the US high school screening process was scrutinized and found to be lacking.⁴⁵ Forty percent of the individual states had either no formal screening requirement or a history and physical examination questionnaire form from the State High School Association that was judged to be incomplete and inadequate (containing zero or ≤ 4 of the 12 AHA-recommended elements) for reliably raising the suspicion of cardiovascular disease. In a recent preliminary analysis, revisiting this issue

8 years later in 2005,⁴⁶ a striking improvement was evident in the state questionnaire forms for medical clearance. Eighty-one percent of the states are now judged to have adequate questionnaires, with ≥ 9 of 12 AHA-recommended items, whereas only 2% of the states are clearly inadequate, with ≤ 4 AHA items. Between 1997 and 2005, the mean number of items on screening forms increased from 6.8 ± 7 to 9.7 ± 7 , an improvement of 43%. However, the number of states in which nonphysician examiners are now permitted by legislation to perform athlete screening has increased by 64%. Eighteen states (35%) permit chiropractors or naturopathic practitioners to screen athletes.

Colleges

In contrast to high schools, colleges and universities usually conduct preparticipation screening within a preexisting infrastructure (with dedicated team physicians, trainers, and on-campus health centers). Traditionally, member institutions of the NCAA have been independently responsible for their own preparticipation evaluation process and the design of the institutional screening history and physical examination. Approximately 25% of colleges and universities have been judged to have inadequate screening questionnaires.⁴⁷

The NCAA has long recommended an evaluation for student-athletes before athletic participation. Recently, however, the NCAA Committee on Competitive Safeguards and Medical Aspects of Sports has mandated a preparticipation evaluation for all collegiate athletes in Divisions I, II, and III before their first practice or competition. The NCAA also recommends that these evaluations be performed or supervised by a qualified physician on the basis of the cardiovascular recommendations outlined in the 2005 *Preparticipation Physical Evaluation* monograph.²⁵ This document represents the collaborative effort of the American Academies of Family Physicians and Pediatrics, the American College of Sports Medicine, and several other medical societies. It has adopted 10 of the 12 recommended history and physical examination items promoted by the AHA, omitting only a history of fatigability and Marfan stigmata on examination.

Professionals

Professional sports represent an environment for preparticipation screening that differs considerably in several important respects from the customary practice in high schools and colleges.⁴⁸ Professional athletes in the 4 major North American sports leagues (National Basketball Association [NBA], National Football League [NFL], National Hockey League [NHL], and Major League Baseball [MLB]) and in other venues represent a relatively small cohort (≈ 4000) in comparison with athletes in US high school programs (estimated 5 to 6 million). Second, professional athletes are largely of adult age (≥ 21 years) and employed under complex labor contracts with their teams and player unions, and they are also compensated for their services. Third, professional teams possess the financial resources to support more comprehensive screening initiatives with noninvasive testing (eg, with ECG, echocardiography, and exercise stress testing). Indeed, a variety of nonstandardized preparticipation screening strategies, which vary considerably in scope⁴⁸ but often include

diagnostic testing,^{48–50} constitute customary practice among professional sports teams. The NBA has recently mandated standardized screening with echocardiography and ECGs for all players on an annual basis (starting with the 2006 to 2007 season). In contrast, although NFL teams generally perform ECGs, echocardiograms are obtained only if clinically indicated.

Olympic Games

Since 1996, the US Olympic Committee medical staff has administered preparticipation history and physical examination in a format similar to that eventually recommended in the 1996 AHA screening guidelines. These examinations are conducted during athlete processing 4 to 6 weeks before the Summer and Winter Olympic Games. No US athlete has ever been disqualified from the Olympic Games because of cardiovascular disease detected on the preparticipation examination or has died suddenly from heart disease during Olympic competition. Noninvasive testing is performed only when warranted by the history and physical examination.

Expectations of Standard Screening Procedures

Preparticipation screening by history and physical examination alone (without noninvasive testing) does not have sufficient sensitivity to guarantee detection of all cardiovascular abnormalities linked to sudden death in young athletes. Indeed, customary screening practices in the United States may be encumbered by substantial false-negative results. The standard personal history conveys low sensitivity and specificity for detection of many cardiovascular abnormalities pertinent to young athletes, particularly when symptoms such as chest pain or lightheadedness are elicited. Congenital aortic valve stenosis is probably the condition most likely to be detected reliably during routine screening because of the characteristically loud systolic heart murmur.

On the other hand, detection of HCM by the standard screening examination may be unreliable because most such patients do not have outflow gradients under resting conditions,⁵¹ and therefore no or only a soft heart murmur may be heard. Auscultation performed in the standing position (or with Valsalva maneuver) may, however, unmask a loud murmur due to dynamic left ventricular outflow obstruction (Table). Furthermore, most athletes with HCM do not have a history of syncope or a family history of premature sudden death related to HCM that could alert the examiner. In addition, physical findings do not reliably identify athletes with congenital coronary anomalies of wrong sinus origin and ion channelopathies such as long-QT syndrome, and only selected items in the personal and family history will be useful in raising suspicion of these diseases. In older athletes (≈ 35 to 40 years of age or older), a history of coronary risk factors, including a family history of ischemic heart disease, is useful in identifying at-risk individuals.³⁰

Effectiveness and Limitations of Noninvasive Screening Tests

Echocardiograms

The addition of noninvasive diagnostic tests to the screening process clearly has the potential to enhance the detection of

certain cardiovascular defects in young athletes. For example, 2-dimensional echocardiography is the principal diagnostic tool for clinical recognition of HCM by virtue of demonstrating otherwise unexplained asymmetrical left ventricular wall thickening, the *sine qua non* of the disease.³² Screening large populations for HCM with genetic testing is highly impractical, given the cost, substantial mutational heterogeneity, and the anticipated frequency of false-negative test results.⁵²

It is a reasonable expectation that echocardiography can also detect other relevant abnormalities responsible for sudden death in young athletes, such as aortic stenosis and mitral valve prolapse, aortic root dilatation associated with Marfan syndrome or bicuspid aortic valve, dilated cardiomyopathy and other forms of left ventricular dysfunction, and possibly, arrhythmogenic right ventricular cardiomyopathy.²¹ However, even such diagnostic testing does not guarantee the identification of all clinically relevant abnormalities.

Realistically, some diseases are beyond detection with any mass screening strategy, even when diagnostic testing is in expert hands. For example, definitive documentation of congenital coronary artery anomalies of wrong sinus origin (most commonly, left main coronary from right sinus of Valsalva) usually requires sophisticated laboratory examination, ie, coronary arteriography, transesophageal echocardiography, cardiac magnetic resonance imaging, or computed tomography angiography. However, on occasion, it is possible to identify or raise the suspicion of anomalous left coronary artery with standard transthoracic echocardiography. Also, many cardiovascular abnormalities must be distinguished from the physiological and benign profile of athlete's heart.^{1,20}

Electrocardiogram

European investigators have promoted the 12-lead ECG as a practical and cost-efficient strategy for population-based screening. ECGs are abnormal in >90% of patients with HCM^{52,53} (and arrhythmogenic right ventricular cardiomyopathy) and can detect ion channelopathies such as long-QT syndrome and Brugada syndrome. However, the resting ECG is usually normal in catecholaminergic polymorphic ventricular tachycardia, and exercise testing is required for diagnosis. The ECG has relatively low specificity as a screening test in athletic populations largely because of the high frequency of ECG alterations associated with the normal physiological adaptations of the trained athlete's heart.

In the United States, screening results have been reported only in relatively small studies of high school and college athletes (250 to 2000 subjects) with diverse study designs,^{54,55} including one using the ECG as a primary screening test.⁵⁵ In general, these efforts yielded few important cardiovascular abnormalities, likely because of the small cohort sizes. In screening older trained athletes, routine application of exercise testing for the detection of coronary artery disease would have the limitation of low specificity and pretest probability.

Cost Considerations

Of critical concern in considering any large-scale screening program is the cost-effectiveness of the recommended strategy. Unfortunately, with regard to cardiovascular screening

of competitive athletes, only very limited (and somewhat outdated) cost-effectiveness data exist to guide recommendations.^{56,57} On close inspection, the absolute cost would be enormous for a national preparticipation screening program carried out in the United States on an annual basis with routine ECG testing (consistent with the Italian model).

For example, if we assume 10 million high school and middle school athletes would be eligible for annual screening with costs (based on Center for Medicare Services–approved reimbursements) of \$25 per each personal and family history and physical examination and \$50 for each ECG, the expense for the primary evaluations would be \$750 million. These basic costs are \approx 2-fold those estimated for Italy.⁵⁸ In addition, positive results in history, physical examination, or ECG could be expected to affect an estimated 15%^{18,55} of the 10 million screened athletes (1.5 million). This would trigger a noninvasive cardiac evaluation that would include another history and physical examination (\$100) and 2-dimensional echocardiogram (\$400). This secondary evaluation would add \$750 million (and probably more) to the cost of the program each year, which would make the minimum annual total \$1.5 billion. However, this analysis does not take into account all the considerable administrative resources and costs necessary to operate a program of this magnitude, including permanent staff, compensation to examiners and technicians, and additional testing (in addition to echocardiography) and other medical expenses in selected athletes suspected of having cardiovascular disease. We estimate this could add another \$500 million to the overall program cost, for an annual total of \$2.0 billion.

By relying on the known prevalence in the general population for diseases such as HCM, arrhythmogenic right ventricular cardiomyopathy, and ion channelopathies (conservatively 1:1000), we can assume that \approx 10 000 athletes (of the 10 million) would harbor these unsuspected cardiac diseases that are ultimately detectable by mass screening with ECG. Of these 10 000 athletes, \approx 9000 are likely to have an abnormal ECG pattern that would raise suspicion of cardiac disease during the screening process.

Given the theoretical cost of a mass cardiovascular screening program of \$2 billion per year, the dollar amount attached to detecting each athlete with the suspected relevant cardiac diseases would be \$330 000. Assuming that \approx 10% of these 9000 athletes with cardiac disease (1800) would harbor evidence of increased risk for sudden death,⁵⁹ then the cost of preventing each theoretical death would be \$3.4 million. We recognize that some may not regard these estimated costs per athlete as excessive for detecting potentially lethal cardiovascular disease in young people; however, the fundamental issue defined by these calculations concerns the practicality and feasibility of establishing a continuous annual national program for many years at a cost of approximately \$2 billion per year.

Volunteer Efforts

Recently, some volunteer and community-based cardiac screening initiatives have emerged, including programs in which portable echocardiograms (in addition to a limited personal and family history) are used to assess high school

athletes, largely for HCM detection. These nonprofit efforts are organized under unique circumstances in which echocardiographic equipment is donated and professional services are volunteered. Despite the benevolent intentions and potential benefit of such initiatives, these screening approaches may not fall within the scope of the traditional patient-physician relationship, and thus, they create uncertain areas of liability. Also, such volunteer public service projects cannot easily be sustained financially and are very unlikely to be implemented on a regional or national scale.

European Versus American Perspectives on Screening

European Recommendations

In 2004–2005, the ESC¹⁶ and IOC^{26,27} presented initiatives addressing methodology for cardiovascular screening in large populations of young trained athletes. These proposals advocate combining noninvasive testing (ie, a 12-lead ECG) with the standard history-taking and physical examination. The premise of this screening strategy is that the ECG is a powerful tool in detecting or raising suspicion of many cardiovascular diseases that cause sudden death in young athletes. The European proposal is predicated on the unique 25-year Italian experience with a state-subsidized national program in which all individuals 12 to 35 years of age participating in organized team or individual sports are mandated to obtain annual medical clearance by accredited sports medicine physicians. Clearance is based on history, physical examination, and ECG.⁶⁰

The Italian screening program has been successful in detecting cardiovascular abnormalities, particularly HCM and other cardiomyopathies, which has led to the disqualification of many athletes from competitive sports to reduce their risk of sudden cardiac death.^{18,19} Recent data suggest that this screening and disqualification strategy may, in fact, be life-saving by virtue of reducing cardiovascular events in athletes. Italian investigators attribute a decline in the sudden cardiac death rate during sports to their long-standing systematic national preparticipation screening program, which routinely includes a 12-lead ECG.¹⁹ They report a time-trend analysis showing a substantial decline (almost 90%) in the annual incidence of sudden cardiovascular death in competitive athletes (largely attributable to reduced deaths from cardiomyopathies) for the Veneto region of northeastern Italy.¹⁹ This change occurred in parallel with progressive implementation of nationwide mass screening and the increasing identification of affected athletes, who were then disqualified from competitive sports.

Fundamental to the European (Italian) program is the principle that trained athletes represent a unique subset of the general population who are at higher risk for sudden death because of their unique lifestyle. Therefore, a priority has been assigned to the detection of cardiovascular disease in competitive athletes, which in the process elevates the importance of their potential medical problems beyond those of other members of society.

The American Perspective

The ESC and IOC model, in which an ECG is systematically included in the screening process, is a benevolent and admirable proposal deserving of serious consideration. Indeed, on humanitarian medical grounds, the AHA supports any public health initiative with the potential to identify adverse cardiac abnormalities. On the other hand, because the panel cannot ignore the many epidemiological, social, economic, and other issues that impact this screening proposal, it must view the European model in realistic terms from a US perspective. Therefore, for a number of reasons, it is difficult to consider the European-Italian strategy as potentially applicable to preparticipation screening in the United States.

First, the framework and resources that would permit the comprehensive screening of all competitive athletes in organized sports on a national basis do not exist presently. De novo formulation of such a program seems highly unlikely given the large size of the US population (300 million, or 5 times that of Italy) and the potential athlete cohort to be screened (estimated to be ≈ 10 million, exclusive of youth sports and masters athletes), as well as the wide geographic dissemination of the screening population into diverse rural and urban areas. The United States would also be required to create a statute (such as in Italy) making compliance with screening mandatory and to establish disqualification standards that would be generally accepted and binding. These are daunting tasks given the inevitable conflicting interests. Finally, the ambiguities involved in the diagnosis of those cardiovascular diseases responsible for sudden death in young athletes could themselves create obstacles to the administration of such a mass screening program.

The financial resources, manpower, and logistics required for national screening would be enormous and obviously require substantial subsidization by the federal government. In addition, such a program could be expected to provoke strong opposition on the issue of cost-effectiveness. A program of this scale would have to be unusually efficient to process thousands of athletes in short periods of time and resolve official medical clearance (including athletes with borderline findings) before the onset of training for the many sports and jurisdictions.

In such a large and heterogeneous society as the United States, it is unlikely that sudden deaths in young athletes, which are (fortunately) relatively uncommon events, would achieve sufficiently high priority when competing with a myriad of other public health issues. Also, it would be difficult to arbitrarily exclude from a screening program young people (such as high school students) who could harbor silent but potentially lethal cardiovascular disease simply because they made the choice not to engage in competitive athletics.

Perhaps the primary problem relates to the issue of medical resources, independent of cost considerations. The reservoir also of dedicated physician examiners that would be required for such an ambitious national screening program (including ECG interpretation) does not, in fact, presently exist within the already overburdened US healthcare system. Mass preparticipation screening that presently takes place relies extensively on primary care physicians (most com-

monly without board certification in sports medicine) and nonphysicians with various levels of cardiovascular training and expertise, many of whom provide their services on a voluntary or low-cost basis. In contrast, the Italian national screening program was initially facilitated by an excess of medical school graduates, which allowed the formulation of a cadre of accredited sports medicine physicians who were solely responsible for medical clearance examinations in competitive athletes.⁶⁰

The problem of borderline or false-positive test results, commonly from ECG interpretation, is particularly relevant in evaluating the feasibility of a national athlete screening program. In prior screening efforts of varied design, the percentage of false-positive examinations has ranged from $\approx 10\%$ to 25% ,^{18,55} depending on the threshold criteria used to define an abnormal ECG or a pathological heart murmur. ECG abnormalities occur frequently in athletes, reportedly in 10% to 40% , depending largely on the level of sports training and criteria used for distinguishing abnormal patterns.²⁰

When identified on the primary screening examination, ECG abnormalities often trigger noninvasive diagnostic evaluations with cardiovascular specialists (including echocardiography), which adds considerably to the scope and resources required for a mass screening program. Certainly, many such young athletes would be of low socioeconomic status, without independent resources and medical insurance to cover the. Finally, false-positive screening diagnoses would generate unnecessary life implications, with emotional, financial, and medical burdens for the athlete, family, team, and institution, including unnecessary additional tests and procedures, anxiety, uncertainty, and the possibility of disqualification without merit.

Special Issues Related to Race and Gender

Race

Sudden cardiac death in young competitive athletes is a source of particular concern to the black community. Indeed, of the athletic field deaths due to HCM in high school and college student-athletes, $>50\%$ occur in blacks.⁴ This observation contrasts sharply with the distinct underrepresentation of blacks in clinically identified, hospital-based HCM patient populations. Although this discrepancy has several possible explanations, socioeconomic status and biases within the healthcare system likely limit the access of young blacks to noninvasive diagnostic tests (eg, echocardiography) necessary for an HCM diagnosis.⁴

Gender

Sudden cardiac death during sports is uncommon in young female athletes of any race compared with males, occurring in a ratio of $1:9$.^{4,6,7} The explanation for this disproportionality is not entirely clear but may be explained by lower participation rates in sports and potentially may be due to less severe training demands in some female athletes. Also, women do not participate in football, a sport commonly associated with sudden death in men. No evidence indicates that the availability or quality of preparticipation screening differs significantly with regard to gender or race.

Screening Recommendations

Advisability

The AHA continues to support preparticipation cardiovascular screening for student-athletes and other participants in organized competitive sports as justifiable, necessary, and compelling on the basis of ethical, legal, and medical grounds. Indeed, preparticipation screening for athletes is viewed as an important public health issue. Noninvasive testing can enhance the diagnostic power of the standard history and physical examination. However, the AHA panel does not believe it to be either prudent or practical to recommend the routine use of tests such as 12-lead ECG or echocardiography in the context of mass, universal screening. This view is based on the substantial size of the athlete cohort to be screened, the relatively low prevalence of cardiovascular conditions responsible for sports-related deaths, the limited resources presently available for allocation (and other cost-efficacy considerations), but particularly the absence of a physician-examiner cadre prepared and available to perform and interpret these examinations. Notably, the latter does not currently exist within the US healthcare system, and therefore, the addition of such a screening program to preexisting resources would impose a significant and unrealistic manpower burden. In addition, significant concern exists that the widespread application of noninvasive testing to athletic populations would undoubtedly result in false-positive results well in excess of the number of true-positives, thereby creating unnecessary anxiety among substantial numbers of athletes and their families, as well as the potential for unjustified exclusion from competition. However, this view represents a perspective on large-scale national screening programs and is not intended to actively discourage individual local efforts.

The panel concluded that complete and targeted personal and family history and physical examination (including brachial artery blood pressure measurement) designed to identify or raise the suspicion of those cardiovascular diseases known to cause sudden cardiac death or disease progression in young athletes represent the most practical screening strategy for implementation in large populations of young competitive sports participants in the United States. This medical evaluation should be performed by a qualified examiner and include the 12 key AHA-recommended elements for personal and family history-taking and physical examination, as well as parental verification of the medical history for high school and middle school student-athletes (Table). Examinations should be conducted in a physical environment conducive to optimal auscultation of the heart. Obtaining echocardiograms and/or ECGs as part of preparticipation screening remains optional.

Such an approach is an obtainable objective and should be mandatory for all competitive athletes before their initial engagement in organized sports. Comprehensive screening evaluations should be administered again after 2 years for high school athletes. College student-athletes should be evaluated with a complete history and physical examination on matriculation to the institution before they begin training and competition, and thereafter, an interim history (with

blood pressure measurement) should be administered in each of the subsequent 3 years.⁶¹ Important changes in medical status detected during the solicitation of interim annual histories for college athletes may constitute evidence that another physical examination and possible further testing should be performed.

The panel recommends the development of a national standard for cardiovascular medical evaluations that could be used in the systematic assessment of all high school and college-aged student-athletes, although we are cognizant that this aspiration would require the cooperation and input of many organizations and interested parties. The official recommendations and requirements of athletic governing bodies with regard to the nature and scope of preparticipation medical evaluations are now heterogeneous in design and content, lacking in standardization, and often inconsistent among the states (for high school athletes) or colleges and universities. In many cases, such recommendations cannot be viewed as medically sufficient. Adherence to uniform guidelines would result in the identification of many more athletes with cardiac disease and thereby positively impact the health of student-athletes by enhancing the safety of competitive sports.

For older competitive athletes (≈ 35 to 40 years of age or older), knowledge of a personal history of coronary artery disease risk factors and/or familial occurrence of premature atherosclerotic heart disease is useful in screening for underlying cardiac disease. In addition, it may be useful to selectively perform medically supervised exercise stress testing in men >40 years of age (women >55 years of age) who wish to engage in habitual vigorous training and competitive sports and who have ≥ 2 coronary risk factors (other than age and gender), or possibly a single risk factor if it is markedly abnormal. Older athletes should also be specifically cautioned with regard to the potential significance of prodromal cardiac symptoms, such as exertional chest pain.

Certain insights offered here with regard to screening should not promulgate a false sense of security on the part of medical practitioners or the general public. The standard history and physical examination implicitly lack the power to reliably raise the suspicion of (or identify) certain potentially lethal cardiovascular abnormalities. Indeed, it is unrealistic to expect that standard large-scale athletic screening examinations can exclude all clinically relevant diseases.

Methodology

Preparticipation sports examinations in young athletes are presently performed by a variety of individuals, including physicians (compensated or volunteer) or nonphysician healthcare workers with varying degrees of training or experience. Examiners may be associated with or administratively independent of the concerned institutions, schools, or teams. The panel harbors particular concern about the current practice of 18 states that have legislated for chiropractors or naturopathic clinicians to perform preparticipation high school clearance examinations, despite their lack of formal professional training for such

activities. Consequently, we strongly recommend that cardiovascular athletic screening with history and physical examination be performed only by physicians or other healthcare workers with requisite training, medical skills, and background to reliably recognize or raise reasonable suspicion of heart disease. Although it is preferable that such individuals be licensed physicians, this is not always feasible, and therefore, it is acceptable for nurse practitioners or physician-assistants formally trained in physical examination techniques to perform athletic screening evaluations. Nevertheless, the panel recommends the establishment of a standardized certification process for designated nonphysician examiners to ensure an acceptable level of expertise in performing screening evaluations in young athletes.

We recognize that the accuracy of some responses elicited by history-taking from young sports participants may depend on a level of personal compliance and their depth of medical knowledge, and this issue can have a significant impact on the accuracy of the screening process. Therefore, parents should be responsible for completing the history form for minors. Preparticipation screening is, however, only the first opportunity for recognition of cardiovascular disease. When abnormalities are identified (or suspected) on mass screening, athletes should be referred to a cardiovascular specialist for further evaluation and confirmation.

Conclusions

A large population preparticipation screening initiative for US athletes that mandates a 12-lead ECG, such as that proposed by the ESC and IOC, is probably impractical and would require considerable resources that do not currently exist, as well as substantial long-term federal government subsidization. Although such a complex initiative would have benefit in terms of detecting greater numbers of athletes with important heart diseases, it is unlikely that *de novo* formulation of such a national program could occur because of the numerous aforementioned obstacles. Paradoxically, such screening could also be potentially deleterious to many athletes by virtue of false-positive test results that would lead to unnecessary further evaluations and testing, anxiety, and possibly to disqualification without merit. Although the ESC proposal is innovative and based on a generally favorable long-term experience in Italy, it cannot easily be translated into the US medical system and environment. On the other hand, the panel does not arbitrarily oppose volunteer-based athlete screening programs with noninvasive testing performed selectively on a smaller scale in local communities if well designed and prudently implemented.

The devastating impact of even relatively infrequent sudden death events justifies restriction of young athletes from competition to reduce their risk related to silent and unsuspected cardiac disease. Eligibility and disqualification decisions for future athletic participation in those athletes with cardiovascular abnormalities, based on the degree of medical risk associated with exercise, should be made in accordance with the Bethesda Conference No. 36.¹⁵

Disclosures

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Ownership Interest	Consultant/Advisory Board	Other
Barry J. Maron	Minneapolis Heart Institute Foundation	None	None	None	None	None	None
Paul D. Thompson	Hartford Hospital	None	None	None	None	None	None
Michael J. Ackerman	Mayo Clinic	NIH-HD42569; AHA Established Investigator Award	None	None	None	PGxHealth, Medtronic, CV Therapeutics, Pfizer	None
Gary Balady	Boston University	None	None	None	None	None	None
Stuart Berger	Medical College of Wisconsin	None	None	None	None	None	None
David Cohen	Beth Israel Deaconess Medical Center	None	None	None	None	None	None
Robert Dimeff	The Cleveland Clinic Foundation	None	None	None	None	None	None
Pamela S. Douglas	Duke University	None	None	None	None	None	None
David W. Glover	Saint Luke's Medical Group	None	None	None	None	None	None
Adolph M. Hutter, Jr	Massachusetts General Hospital	None	None	None	None	None	None
Michael D. Krauss	Purdue University	None	None	None	None	None	None
Martin S. Maron	Tufts University	None	None	None	None	None	None
Matthew J. Mitten	Marquette University Law School	None	None	None	None	None	None
William O. Roberts	University of Minnesota School of Medicine	None	None	None	None	None	None
James C. Puffer	American Board of Family Medicine	None	None	None	None	None	None

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Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/Advisory Board	Other
Sana Al-Khatib	Duke University	Medtronic†	None	None	None	None	None	None
Barbara Bentz	Penn State University	None	None	None	None	None	None	None
Vera Bittner	University of Alabama at Birmingham	None	None	None	None	None	None	None
David Cannom	Los Angeles Cardiology Associates	None	None	None	None	None	None	None
Mark Carlson	Case Western Reserve University	None	None	Medtronic*; Biotronic*; Guidant*	None	None	Cameron Health*	St. Jude*; Guidant*
N.A. Mark Estes	New England Medical Center	None	None	None	None	None	None	None
Alan Forker	Mid America Heart Institute	None	None	None	None	None	None	None
Michael Gold	MUSC Medical Center	None	None	None	Guidant*; St. Jude*	None	None	None
David Haines	Beaumont Hospitals	None	None	None	None	None	None	None
Bradley P. Knight	University of Chicago	Guidant†; Medtronic†; St. Jude†	None	Guidant*	None	None	None	Guidant*
Peter Kowey	Cardiovascular Associates of Southeastern Pennsylvania	None	None	None	None	None	None	None
Mark Link	New England Medical Center	None	None	None	None	None	None	None
Patrick E. McBride	University of Wisconsin-Madison	None	None	None	None	None	None	None
Andrea Russo	University of Pennsylvania	Medtronic*; Guidant*; St. Jude*	None	None	Medtronic*; St. Jude*	None	None	None
David Rosenbaum	Case Western Reserve University	St. Jude Medical†	None	None	None	None	None	Cambridge Heart Inc†
John Stephen Strobel	IMA, Inc	None	None	None	None	None	None	None
Reginald Washington	Rocky Mountain Pediatric Cardiology	None	None	None	None	None	None	None

This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be "significant" if (1) the person receives \$10 000 or more during any 12-month period or 5% or more of the person's gross income; or (2) the person owns 5% or more of the voting stock or share of the entity or owns \$10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

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KEY WORDS: AHA Scientific Statement ■ death, sudden ■ exercise ■ prevention ■ automated external defibrillators ■ electrocardiography ■ cardiomyopathy ■ genetics