Among the adolescent and young adult population, the absolute risk of sudden cardiac arrest (SCA) is low, whereas the benefits of identifying predisposing conditions and preventing SCA are disproportionately large.1,2 Competitive athletes included within this population subgroup are at higher risk of SCA than expected for the general population in this age category.3-5 Recently, there has been considerable debate in the United States about the appropriate strategies, effectiveness, and logistics of various preparticipation screening techniques for identifying individuals at risk. Despite the recommendations of the European Society of Cardiology (ESC)6 and the International Olympic Committee (IOC)7 that an ECG be added to the preparticipation screening process, the American Heart Association (AHA) has recently reaffirmed its long-held position on preparticipation screening for cardiovascular abnormalities in competitive athletes.8 The AHA suggests that ECG screening is not warranted as a component of preparticipation evaluations unless specific observations in the history or physical examination exist that trigger a more extensive cardiovascular evaluation.8 This position is retained despite various sources of data supporting an incremental benefit attributable to routine ECG screening.9 General agreement exists on preparticipation screening guidelines that include an appropriate personal medical and family history and physical examination, but the inclusion of additional elements such as an ECG is in dispute. The purpose of this article is to respond to the AHA recommendation and to provide a reasoned alternative approach.

Response by Chaitman p 2626

Overview of Screening for Sudden Death Prediction

SCA leads to unexpected death and affects all segments of society. It is a large public health problem, accounting for at least 50% of all cardiovascular deaths and a higher proportion in selected segments of society.10 From the perspectives of clinical and epidemiological impact, SCA did not receive the attention it deserved until recent years, with recognition notably absent in regard to the adolescent population and competitive athletes.

Age is a powerful determinant of the magnitude of risk of sudden cardiac death (SCD), with an event rate of 1 to 2 per 1000 population per year among the general population ≥35 years of age.11 Within this range, the age-risk curve has a steep slope (Figure 1, middle curve). In the younger subgroups, particularly those in the adolescent and young adult categories (defined as puberty to 35 years of age for the purpose of this discussion), the population risk of SCD is only
1% of that in middle age and older age groups (ie, ≈1 per 100 000 population) (Figure 1, bottom curve).

However, the risk discrepancy between the younger and older age groups must be considered in the context of the greater benefit that improved identification and prevention can provide for the younger population. The cardiovascular disorders responsible for SCA in the younger age group are entities for which prevention or intervention are likely to yield many more years of quality life than is expected in the older population.

Finally, early recognition of risk is important for all age ranges of the population because of estimates that 30% to 50% of all SCDs are first clinical events and up to 67% occur either as first events or among those with identified disease who are profiled to be at low risk. It is likely that the “fatal first event” probability is even higher for SCDs in the younger age groups.

No single strategy for predicting and preventing SCD, standing alone, is sufficiently powerful to have a major impact on the magnitude of this large public health problem. Three fundamental strategies in use today—screening of general populations, risk profiling and interventions among patients with identified disease, and community-based response systems—all contribute to improved outcomes and behave cumulatively in their effects on population sudden death rates. In addition, the evolution of a genetic and genomic knowledge base and related technologies raises the hope that effective and efficient strategies for individual risk prediction will ultimately be developed from the emerging field of genetic epidemiology.

### Historical Perspectives of Preparticipation Screening

Recognition of the problem of SCD risk among adolescents and young adults (with particular emphasis on competitive athletes), followed by recommendations, guidelines, and requirements for the preparticipation cardiovascular screen-

1. **Myerburg and Vetter Athlete ECGs 2617**

![Figure 1. Age-related and disease-specific risk for SCD.](image-url)

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Figure 1. Age-related and disease-specific risk for SCD. For the general population >35 years of age, SCD risk is 0.1% to 0.2% per year (1 per 500 to 1000 population). Among adolescents and young adults, the risk is 1 per 100 000 population or 0.001% per year. In the adolescent–young adult group, the risk is higher at the younger end of the age range because of enhanced expression of inherited disorders after puberty. Modified from Myerburg and Castellanos, with permission from the publisher. Copyright © Elsevier, 2004.
had hypertension (Figure 3). A subsequent evaluation using echocardiography in a similar population who had been previously screened showed the ECG to be 98.8% sensitive for identifying abnormal cardiovascular findings. Evaluation of 42,386 athletes between 1979 and 2004 (12 to 35 years of age) who underwent the Italian screening protocol (standard history, physical examination, and ECG, with an echocardiogram or exercise stress test added if the history, physical examination, or ECG is abnormal) showed that the annual incidence of SCA in athletes decreased by 89%, indicating that the incidence of SCA in athletes, especially from cardiomyopathies, during the period of this screening program had significantly decreased (Figure 4).

Considering the Italian data, the IOC recommended including an ECG in the preparticipation screening of Olympic athletes in 2004, and the ESC followed suit in 2005. The US Olympic Committee continues to follow the 1996/2007 AHA recommendations, which do not include routine ECG screening. The IOC and ESC base their recommended screening strategies on the premise that the ECG has independent added value for detecting a number of the cardiovascular disorders, including cardiomyopathies and channelopathies, that may cause SCD in young athletes. A striking value of proactive ECG screening derives from the data-supported principle, cited above, that an SCA will, with high probability, be a first clinical event in a large proportion, if not the majority, of fatal cases. This principle takes on practical importance now because of the potential of preventing SCD by lifestyle modification or restriction of competitive athletic activities, primary prevention with pharmacological treatments, or primary or secondary prevention by implantable cardioverter-defibrillators. Community-based automated external defibrillators provide a valuable backup for those conditions unrecognized by screening but do not provide the same survival benefit as primary prevention.

Attitudes toward routine ECG screening in younger age groups in the United States, as represented by the AHA statement, are at variance with those in other regions of the world. The United States has not followed the lead of Japan and Europe in adopting this more comprehensive screening strategy. In fact, few ECG screening studies have been

![Figure 2. Italian athlete screening program disqualifications. A. Among 33,735 athletes screened, 621 or 1.8% were disqualified for cardiovascular (CV) reasons. B. Of 22 patients with a diagnosis of HCM, 18 (82%) had an abnormal ECG, whereas only 5 (23%) had a positive family history (FH) or cardiac murmur. Modified from Corrado et al with permission of the publisher. Copyright © 1998, American Medical Association.](image)

![Figure 3. Cardiovascular disqualifications in large screened athlete populations. Most common reasons for disqualification were arrhythmias and hypertension. Other causes include HCM, valvular heart disease, dilated cardiomyopathy, and others. Inset, Types of arrhythmia and conduction abnormalities resulting in disqualification of screened athletes. Ventricular arrhythmias (VA), atrial fibrillation (Afib), and Wolff-Parkinson-White pattern (WPW) were the most common identified, with right (RBBB) or left (LBBB) bundle-branch block, second-degree atrioventricular block (2°AVB), and long-QT syndrome (LQTS) also observed. Modified from Corrado et al with permission of the publisher. Copyright © 1998, American Medical Association.](image)
Inconsistencies and Contradictions in the AHA Update 2007 Strategy

The AHA Update 2007 indicates that the panel was addressing a number of issues related to preparticipation screening, including benefits, limitations, cost-effectiveness, feasibility, medical-legal issues, and ethics, and does not yield on the issue of routine ECG screening. The authors of this document cite numerous obstacles to indicate why they think this approach would be difficult to implement in the United States. Curiously, they do not dispute the incremental value to ECG screening, stating that the ESC and IOC model is “a benevolent and admirable proposal deserving of serious consideration.” However, the document concludes that ECG screening is “impractical and not applicable” to the American system because of the logistics, manpower, and financial resources required for a national screening program. We believe that this dismissive statement is self-determining and that an exploration of the elements of this argument leads to a rational approach, justifying a different resolution to this complex problem.

Limitations of the Current Preparticipation History and Physical Examination in the United States

The preparticipation history and physical examination is the primary screening tool currently used for those involved in organized competitive athletics in the United States. This method for preparticipation screening lacks power for reliable identification of the disorders responsible for SCD. This is well illustrated by a report by Maron et al23 of 134 athletes who died suddenly and in whom the screening history and physical examination led to a suspicion of an underlying disorder in only 3% and to an accurate diagnosis in <1% of those examined.22 Recognition of the limitation of the current system should lead to the logical conclusion that changes should be made.

Currently, the approaches to preparticipation screening remain very similar among high school, college, and Olympic athletes in the United States. Conversely, 92% of US professional athletes receive routine screening ECGs.15,16,23 Some colleges offer screening beyond the AHA-recommended history and physical examination,8 as do a few high schools, but to a much lesser extent. The paradox in this strategy is that the risk of SCA and cumulative number of deaths are higher in the younger athletes, many of whom are expressing genetically based disorders beginning at puberty or early adolescence, than in the older professional athletes (Figure 1). The professional athlete belongs to a selection-biased older subgroup in which higher-risk mutations or more obvious phenotypic or pathophysiologic expressions are more likely to have been identified previously.

After the AHA recommendations in 1996, screening by history and physical examination was found to be limited by inconsistencies in personnel and forms used across states. In 1998, a study found that 40% of states had inadequate history and physical examination screening, having no approved history questionnaire or physical examination form, no formal screening requirement, or forms judged to be inadequate. Only 17% included all of the required elements,24,25 and reviews of high school and college preparticipation screening programs indicate that only 26% of college forms met even 75% of the AHA guideline components.25,26 A more recent evaluation in 2005 suggested that >80% were adequate.27 Furthermore, concerns have been raised over the low sensitivity and cost-effectiveness of the preparticipation history and physical examination.28 In fact, Maron29 has stated that the history and physical examination is “a strategy that
lacks sufficient power to identify important cardiovascular abnormalities consistently."

More than one third of the current high school evaluations are being carried out by nonphysician personnel, as noted in the AHA Update 2007, and although the update recommends that this be corrected, one of the major concerns with an ECG screening program relates to the use of proper examiners. This issue needs to be corrected immediately whether ECGs are done or not. Once it is corrected, it will be even easier to have individuals present who are competent to make an initial ECG interpretation.

The argument that too many athletes exist in the United States (at least 0.5% of the population)30 to have a successful program (that has the potential to save several lives) obscures the potential to prevent deaths of otherwise healthy young people. The fact that we do not know how many athletes are dying each year (certainly more than the Centers for Disease Control and Prevention has recorded) highlights the need for a national registry that could be used to refine incidence estimates and to evaluate a screening program that includes the ECG. This need, however, does not argue against adding prevention opportunities in the interim.

Benefits of ECG Screening

The lead author of the AHA Update 2007 has written extensively about the benefits of the ECG in diagnosing conditions that lead to SCA. Certain ECG findings are characteristic in HCM,4,31 and Maron’s32 review of HCM in 2002 stated that the ECG was abnormal in 95% of these patients. In addition, Panza and Maron33 and others34 have reported that an abnormal ECG is an early marker that may precede the appearance of left ventricular hypertrophy on the echocardiogram and symptoms. In the Italian preparticipation study, the ECG had a 77% greater power to detect HCM than the history and physical examination alone.4

Among the other cases of SCA in this age group, 80% of patients with arrhythmogenic right ventricular dysplasia have ECG abnormalities,35–37 as do high proportions of patients with long-QT and Brugada syndromes and dilated cardiomyopathy.

Limitations of ECG Screening in the Target Population

It is generally agreed that ECG interpretation, particularly in regard to recognizing the limits of normal, is a challenge in adolescents, especially in athletes. Standards applicable to the adult population do not necessarily hold for young athletes, among whom a variety of nonspecific variations in both QRS voltage and ST-T wave configuration are common. Many pediatric cardiologists use the criteria of Davignon et al38 published in 1979. A variety of other ECG standards are used by readers of pediatric and adult ECGs. Normal values for QT intervals and conduction intervals have been established.39 Revision of these standards for the young population, including variations by age, gender, ethnicity, and race, as well as expected variations associated with various types and levels of sports activity, would be an expected outcome of a large-scale evaluation program using ECGs.

### ECG Changes in Association With Athletic Training or “Athlete’s Heart”

The success of any screening program is determined by the ability to appropriately identify high-risk individuals without having a large number of false positives or false negatives. In regard to ECG screening, recent data from the Italian program address the concerns of false-positive ECGs.40 The 12-lead ECG was interpreted as normal in 88.2% and abnormal in 11.8% of this population. Abnormalities were considered benign and related to athletic training in 7% and more significant in 4.8% (see the Table).40 The relatively low number of individuals who would need more advanced testing should not be prohibitive within the current US healthcare system. The recently published European data indicate that there should be less concern about false-positive ECGs than is indicated in the AHA publication, which cites a 10% to 25% false-positive rate. Additionally, these data suggest that, taking the level of training and type of sport into account, the addition of an ECG can generally differentiate between athletic heart and true cardiac pathology.2

More pronounced abnormalities are to be expected in the more elite athletes, as has been reported.41 The more elite an athlete is, the more likely he or she will have ECG abnormalities that either are not at all correlated with his or her physiological state or represent the “physiological” changes of the “athletic heart.” Mildly abnormal (ie, “benign”) ECG patterns have previously been reported in 40% of trained athletes, with up to 14% having more significantly abnormal findings.40,42 Athletes in the endurance sports of cycling, rowing, and cross-country skiing are more likely to have ECG abnormalities of a more concerning nature. Similarly, male and young athletes are more likely to show abnormal ECG findings than female athletes, suggesting a greater tendency to ventricular remodeling with training in these groups. If one

### Table. Common and Less Common and Significant ECG Abnormalities

<table>
<thead>
<tr>
<th>Common Benign ECG Abnormalities, 7%</th>
<th>Less Common and Potentially Significant ECG Abnormalities, 4.8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus bradycardia</td>
<td>Left atrial enlargement</td>
</tr>
<tr>
<td>First-degree atrioventricular block or increased PR interval</td>
<td>ST-segment depression</td>
</tr>
<tr>
<td>Incomplete right bundle branch block</td>
<td>Pathological Q waves</td>
</tr>
<tr>
<td>Early repolarization</td>
<td>Inverted T waves in ≥2 leads</td>
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<td></td>
<td>Increased R/S voltages (left ventricular hypertrophy)</td>
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<tr>
<td></td>
<td>Wolff-Parkinson-White pattern</td>
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<tr>
<td></td>
<td>Right bundle-branch block</td>
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<tr>
<td></td>
<td>Left bundle-branch block</td>
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<td></td>
<td>Prolonged QTc interval</td>
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</table>

Modified from Pelliccia et al.42
screens a less “athletic” population than middle school or many high school athletes at an age when variations associated with athletic training may not have developed, the false-positives would be expected to decrease significantly.

Even if the problem of standard criteria is resolved, it must still be recognized that not all causes of SCA in athletes can be recognized reliably on a resting 12-lead ECG (eg, anomalous origin of a coronary artery) and that some causes may have variable expression from time to time (eg, long-QT syndrome, Brugada) or subtle findings in the young (arrhythmogenic right ventricular dysplasia). Nonetheless, studies of the causes of sudden death in athletes and their relative frequencies suggest that at least 70% of those individuals at risk because of preexisting disorders (and up to 90% for certain conditions) can be identified or suspected by findings on a screening ECG.

Logistics and Manpower Limitations of Large-Scale ECG Screening

The 2007 AHA Update of the guidelines for preparticipation screening cites infrastructural factors as a major limitation to implementation of screening programs in the United States, even though they have been successfully implemented elsewhere. One claim is that insufficient numbers of physicians are adequately knowledgeable in the field of adolescent electrocardiography; another is the absence of a basic infrastructure to carry out the screening of the estimated 10 million middle and high school athletes. Because large-scale ECG screening of adolescent athletes has not been undertaken in the United States in the past, the infrastructure for this specific effort does not exist. However, an infrastructure for general preparticipation screening does exist, and an ECG can be appended. Furthermore, the absence of infrastructural support is not justification for dispelling the notion that such a program has societal value. Societal acceptance of inferred benefit relies in part on the actions and statements of respected organizations such as the AHA. Statements from such groups—negative or positive—have a powerful impact. Even if an infrastructure for routine ECG screening in high school athletes could not be implemented rapidly, it could, with proper planning, be phased in over a period of several years once the decision is made that such a program had merit.

Between 3 and 6 million Italian athletes (age range = 12 to 35 years) are screened annually. In the United States, 5 to 10 million high school and middle school students and 0.5 million college students are athletes. Given the number of physicians (including cardiologists, pediatricians, internists, sports medicine, and family physicians) and physician extenders (physician assistants and advanced practice nurses) in the United States, especially those with an interest in SCA, it is not difficult to imagine a system that could be put in place in communities to accomplish screening of high school athletes and eventually to extend that system to all children. The preparticipation history and physical examination is already recommended and being performed in many school settings. The new component would be the ECG, and this also could be obtained in a school setting. Although the US population is 5 times that of Italy, it would appear that we would be screening only 2 to 3 times the number of athletes that the Italians are screening each year. It is not necessary to screen every college, high school, and middle school athlete on a yearly basis, as is done in Italy. In reality, we might need to screen only one half to one quarter of the athletes each year. The preparticipation history and physical examination could include an ECG in middle school, followed subsequently by an ECG added to the preparticipation sports evaluation in high school. Each young athlete would have 2 opportunities to have full screening, including an ECG, during his or her highest-risk years. The current preparticipation history and physical methodology would be used in the intervening years. This could be implemented in the school setting by teaching ECG technical personnel or even parents (as was done in the Chicago area study that has screened 20 000 high school students) to record the ECGs during the school physical examination (Joseph C. Marek, MD, personal communication, May 7, 2007).

Unfortunately, computerized electrocardiography often is unreliable in the targeted age range of this athletic population, necessitating an overread of the computerized interpretation. A manual of “normal” ECG values could be developed from current data and revised as research from the thousands of young athletes screened provides more specific data. This process could lead to new algorithms for the computerized systems. As time progresses, these better-defined criteria for the different adolescent groups will emerge, including tighter standards for the different groups that could be programmed into interpretative algorithms for computerized interpretation.

Large population studies are needed to determine normal values for different age groups, genders, races, and ethnicities, as well as different levels and types of athletic training. The number of individuals who would fall outside those norms would be less than with the current standards, resulting in fewer referrals for additional testing.

With regard to college athletic programs, most have athletic trainers who could be trained to record the ECGs and team physicians who could interpret them or know when to refer. All college athletes are required to have health insurance, and if an abnormality is found, they should have coverage for further testing.

Rationale and Feasibility of Implementing ECG Screening Programs

Given the general agreement, even in the 2007 update of the AHA guidelines for preparticipation screening, that ECGs add value to routine screening, it is our opinion that the infrastructure and economic arguments lack merit on both an absolute cost/cost-effectiveness basis and a relative benefit basis. More important, although there may be a limited basis for the argument that the absence of an existing infrastructure...
for routine ECG screening is an impediment to implementation, the use of this argument as a basis for not moving forward to improve an inadequate method is a self-fulfilling and unsuitable determinant of outcome. Moreover, the AHA, as a respected scientific and public education organization, should be more focused on the scientific and clinical service merits of this screening strategy, with other elements of society dealing with costs and recommended strategies (eg, healthcare policy makers, clinical service providers, school districts, and colleges). It is self-defeating and contradictory to yield on potential value and simultaneously argue against implementation for the reasons given.

The implementation of desirable new programs that have a merit for society has been dealt with many times throughout medical history, with the absence of an infrastructure overcome by determined program development. In the case of ECG screening, a method analogous to universal deployment of automated external defibrillators in US airlines is certainly feasible. In that model, the Federal Aviation Administration set a time limit for implementation once the decision was made that this strategy merited implementation (Federal Aviation Administration Final Rule). A similar model could be used to implement preparticipation ECG screening. Specifically, the AHA and other relevant organizations should change their position and recommend full implementation over a period of 3 to 5 years, with early participation encouraged for any schools or school districts that wish to implement these programs before the target date.

Financial Resources: Costs and Cost-Effectiveness

In the AHA 2007 Update, the cost of the Italian/ESC/IOC type of screening is stated to be too great for the US health system, whereas the US cost-effectiveness data are said to be “outdated” and a “theoretical” cost is proposed as a justification for not screening US athletes with ECGs. The AHA 2007 Update—proposed cost of $2 billion for an athletic screening program was made without any adjustment for efficiencies that could be realized in a standardized screening program. The calculation is based on annual recordings for an estimated 10 million student athletes. The need for annual tracings is questionable, as is the basis for the estimated cost of $50 for an ECG. The Medicare global allowable charge for an office-based ECG in Florida is $29.24. It is likely that mass screening strategies can be negotiated at rates considerably lower than that figure because the cost of ECGs done on a large scale is much less than the current cost of an ECG in an office or hospital setting. A negotiated cost of a screening ECG done on a large scale might be as low as $10 per ECG.

Although there would certainly be costs to build this infrastructure, much of it is in place at this time and does not need to be reinvented. The current method of using preparticipation history and physical forms with the 12 AHA recommended components should still be used, with the ECG added periodically. Between 5% and 10% of those screened would be referred for further testing. This should not be considered unnecessary testing any more than referring a child to a pediatric cardiologist for a murmur that is found to be innocent or an adult to a cardiologist for chest pain that is found to be secondary to gastroesophageal reflux is “unnecessary.” The referral of a young person for further evaluation will find those who are at risk for SCA.

Cost-Effectiveness of ECG Screening

The cost-effectiveness of using ECGs as a mass screening tool is being debated. In the screening study of Nevada high school athletes, ECG screening was estimated to be more cost-effective than history and physical examination alone. The estimated cost per year of life saved was $44 000 with ECGs versus $84 000 for history and physical examination alone. These figures include the cost of the additional testing of the 10% of athletes (582 of 5615) who underwent echocardiogram or other testing to further investigate abnormalities in history, physical examination, or ECG. Most notable is the indication that screening 700 000 high school athletes annually results in 1080 years of life gained when an ECG is used compared with 92 years for the AHA-recommended history and physical examination. Additionally, the Italian screening protocol, compared with the US program, has a 3-fold greater cost-effectiveness for identifying and preventing SCA in athletes with HCM. The cost-effectiveness of the screening program in Japan was estimated at $8800 per year of life saved.

All of the reports on the cost-effectiveness of ECG studies, whether in Japan, Italy, or the United States, have shown a cost per year of life saved well below the $50 000 figure that is used in public health policy discussions (Figure 5). On the basis of these estimates and the real cost of mass ECG
screening in the United States, it is likely that a system could be put into place for <20% to 25% of the cost suggested in the AHA statement. The authors of the AHA statement should not disregard the existing cost-effectiveness data if they have no contrary evidence-based data to support their conclusion.

A characteristic of the younger population that affects the cost-benefit considerations of adding ECGs to preparticipation screening, as well as screening of the general adolescent and young adult population, is the large contribution of genetically based disorders among the causes of SCA. Once a previously undiagnosed genetic disorder is identified in a single individual, screening of family members results in an efficient multiplier effect for additional case finding. Furthermore, in addition to finding children at risk for SCA, up to 3% to 6% of children screened may have a congenital heart defect identified, adding to the cost-effectiveness of ECG screening.44,46

It has been shown in many areas that preventive care is more cost-effective in the long run than treating the aftereffects of a disease or event such as an SCA with resultant inadequate resuscitation and neurological or other sequelae.

Ethical Considerations

It is stated in the AHA Update 2007 that “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.” This implies that ECG screening is “appropriate” for those with available financial resources or access to a benevolent group to fund screening but is not supported as a matter of policy that would provide equal access to all segments of society. This attitude is reinforced in the AHA statement by the inference that it is appropriate for professional teams to be screened because they are “compensated for their services” and that the professional teams have the financial resources.23 This line of reasoning is ethically troublesome. Recommendations from learned scientific organizations should be general statements made on the basis of best available evidence. The impact should not be diluted by endorsing selective application based on healthcare resource distribution. With 25 million uninsured children and adolescents in this country, using means to determine policy fails to protect those who cannot pay for themselves. Rather than providing an escape, a scientific statement should define what is best for all, shifting the policy making and implementation responsibilities to the segments of society where they belong.

As an example, the racial mix in the sports associated with the highest risk for SCA (basketball and football) is skewed disproportionately from the general demographics of the country. This is paralleled by the observation by Maron et al22 that black athletes account disproportionately (≥40%) for the field deaths of elite athletes. With >100 million minorities in our population, the argument that we cannot reproduce the results of the Italian study because the “homogeneity” of their population differs from our heterogeneous population is also ethically troublesome. It is time that we recognize that variations exist in health needs CHARACTERISTICS of different populations, including gender, race, and ethnicity, and embark on programs that include research that will allow us to determine normal values for all populations and thus provide the highest level of care to all groups in our very diverse country.

The argument that the inability to achieve a “zero risk” is a mitigating factor for preparticipation screening efforts reflects a flawed perception of expectations from any type of screening or intervention. All epidemiological and intervention strategies in cardiovascular medicine are based on risk reduction, with an expectation of residual risk.47 The ethical argument supports the premise that the effort should be undertaken if the condition for which one is screening is serious and that, when found, a reasonable intervention or treatment exists that is likely to change the course of the condition. The conditions that cause SCA fit these criteria.

Medical-Legal Concerns

Two general areas of medical-legal impact relate to ECG screening for adolescents, especially for young athletes: potential legal conflict on the question of the right to participate if an abnormality is identified or, conversely, the right to refuse ECG screening and still be allowed to participate and the medical malpractice implications of ECG interpretations that fail to identify a condition that is present.

In regard to the participation issue, case law preserves the right of an institution to prohibit participation on the basis of the presence of a medical condition interpreted to constitute a risk to the athlete.45,49 Although this is established precedent for certain jurisdictions under specific conditions, the broader scope of the question as it relates to individual cases is not settled.49 The question of right to participate and right to exclude will undoubtedly be tested again. Although this issue is independent of whether ECG screening becomes routine, except for the question of the right to refuse such testing, large-scale ECG screening will undoubtedly increase the number of challenges brought forward.

With regard to the concern about disqualification of an individual who wishes to compete, school screening is but the first step in a process that leads to a recommendation that further testing be done and that a specialist in the specific area (eg, arrhythmia, long-QT syndrome, HCM, hypertension, and congenital heart disease) be seen. Those athletes with treatable conditions such as hypertension may be restricted a short time. Those with other conditions could ask their personal physician to make recommendations for sports activities that might be modified for an individual with specific conditions. The Bethesda Guidelines16 and the AHA recreational sports guidelines for cardiovascular genetic condition can serve as general guidelines, but the specific schools will have their own policies.51
The medical malpractice issue related to the ECG should not be different from the considerations in the current preparticipation evaluation. From the standard-of-care perspective, it must be recognized at the present time that the relevant scientific and clinical communities have not succeeded in determining generally accepted standards for defining the limits of normal, or variations of normal, for the interpretation of ECGs recorded from adolescents and young adults, especially athletes.\(^{40,42,52,53}\) The subject should be informed of this limitation. He or she should be told that the preparticipation evaluation, including the ECG, will not diagnose all present or future cardiac conditions and that any change in symptoms or physical findings should be reported to his or her physician immediately. Some of the current screening groups use a waiver stating the above reality. Using the argument that the addition of an ECG to preparticipation screening will result in fewer physicians willing to participate in screening programs is an extremely negative tactic that is not based on evidence, experience, or precedent.

For the future, the development of more reliable ECG criteria for different groups will provide standards for ECG reading both in athletes and in the general young population. Deviation from these standards should be no more problematic in the screening setting than it is in the practice setting. As in the airline automated external defibrillator story, it can be anticipated that the time will come when the legal liability will fall on those who did not look for life-threatening conditions and are held liable when a young person is allowed to participate and experiences SCA. In fact, cases have already been brought against school districts and physicians for not finding conditions that resulted in an SCA or for not restricting such individuals.

**Research Benefit of Program Implementation**

An initiative that will lead to broader use of ECG screening in this population undoubtedly would lead to investigative efforts to better define the correlation between nonspecific ECG changes and anatomic or pathophysiologic changes on echocardiography or other testing techniques. Once it is agreed that this added knowledge has practical application, the rationale for funding the needed research will find acceptance. Until then, it is likely to remain a fringe issue to funding agencies, which often are reticent to place scarce research dollars into areas of investigation that could have limited impact in terms of use.

The conventional research model for testing the reliability of a diagnostic procedure is to carry out a prospective test of criteria for positive and negative accuracy before applying it for routine clinical use. Existing data have identified incremental benefits of identifying individuals at risk and reducing the number of athletics-related deaths.\(^9\) This provides a rationale for using ECG screening even with recognition that better diagnostic criteria are needed. Importantly, the consequence of delays in implementing ECG screening programs until diagnostic criteria are optimized would come at the cost of failure to prevent deaths from occurring during the period of time that the research effort is being conducted. From these facts, it is rational to consider an alternative approach to improving the scientific basis for ECG interpretation in parallel with program implementation. Specifically, by developing a detailed registry on ECG findings and comparing the observations with definitive diagnostic outcomes, it should be possible to develop more reliable standards as a continuous improvement strategy going forward into the future—and saving lives along the way.

**ECG Screening for the General Adolescent and Young Adult Population**

The comments above largely address issues in organized sports within school systems and colleges because these are areas of defined structure in which specific debates have occurred. Many children, adolescents, and young adults participate in various levels of play, physical activity, nonorganized competitive sports, and intensive physical conditioning programs. More than 25 million children and adolescents who do not participate in school-related sports teams but participate in various physical activities will be overlooked if ECG screening is limited to athletes. Some conditions predispose to SCD in the adolescent and young adult age group without the association of physical activity. Examples include specific medications in genetically susceptible individuals (long-QT syndrome) and deaths during sleep (Brugada syndrome and long-QT syndrome type 3).

Accordingly, it can be argued that the rationale of ECG screening for competitive athletes should be extended to all children, adolescents, and young adults as the logistics of cardiovascular screening are developed for the athlete population. The program in Japan with ECGs for children and adolescents at different predetermined ages constitutes a strategy that identifies risk among the population of individuals who would be expected to have a normal or near-normal longevity if sudden death risk is identified in their profiles and addressed as a result of early recognition. Similarly, the Italian newborn ECG screening program is a strategy proposed to identify a subgroup of infants at risk for sudden infant death syndrome and to provide them life-long protection.\(^{34,55}\)

**Conclusions**

The AHA and the Writing Committee of its Council on Nutrition, Physical Activity, and Metabolism should reconsider the recommendation on routine ECGs as stated in the 2007 Update on preparticipation screening. Following the procedural precedent set by its 1998 amendment to the 1996 AHA Statement on preparticipation screening, the AHA writing group should recommend phased implementation of adding an ECG to the preparticipation evaluation process on the basis of the recognition of the value of the test in existing data cited here. The group should simultaneously encourage research strategies for continuous improvement of our knowl-
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Disclosures

None.

References

Response to Myerburg and Vetter

Bernard R. Chaitman, MD

Drs Myerburg and Vetter argue that the 2007 AHA Update on preparticipation screening of athletes should recommend routine ECG recordings for all athletes on the basis of current scientific evidence and not worry about the implementation process that would be handled by healthcare policy makers and program developers. This is a premature recommendation because the existing scientific evidence is insufficient to prove that adding an ECG to the screening process will adequately identify young athletes who will die suddenly in a US population for the reasons outlined in my commentary; furthermore, the cost-effectiveness of this approach remains to be determined. We both agree that new research strategies would be valuable to improve our knowledge base in this area and provide physicians and policy makers with useful data to best determine whether routine ECG screening (and which ECG variables) added to the currently recommended preparticipation examination has sufficient diagnostic accuracy to identify high-risk athletes. One potential approach to resolving this issue might be to conduct a randomized trial of preparticipation screening with or without ECG recordings in a higher-risk athletic subset (eg, young men playing high-intensity contact sports such as football and basketball). If the 12-lead ECG does not have sufficient diagnostic accuracy in this cohort (ie, adequate sensitivity/specificity to identify future sudden death), it is less likely to be useful in lower-risk groups. For now, ECGs should be reserved for those athletes who fail the standard AHA preparticipation examination or on request in concerned individuals.