

## Should an electrocardiogram be included in routine preparticipation screening of young athletes?

### *An Electrocardiogram Should Not Be Included in Routine Preparticipation Screening of Young Athletes*

Bernard R. Chaitman, MD, FACC

The sudden death of a young athlete during competition is a tragic yet rare occurrence that results in significant public and media attention. Increased catecholamine response to maximum stress in subjects with underlying structural heart disease is a well-known cause of lethal cardiac arrhythmias.<sup>1</sup> In 1996, the American Heart Association issued a scientific statement advocating universal cardiovascular preparticipation screening for high school and college athletes in an attempt to identify those at increased risk of cardiovascular events.<sup>2</sup> The recommendations included a 12-point complete history and physical examination (including brachial artery blood pressure measurement) before competitive sports (Table 1) and reserved noninvasive testing such as a 12-lead ECG, echocardiogram, exercise testing, and cardiovascular consultation for athletes in whom any abnormality was detected.

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The recommendations include repeat cardiovascular screening every 2 years with an abbreviated examination in intervening years. Parental participation in gathering a proper history in younger athletes was encouraged. The committee recommended a national standard for preparticipation cardiovascular medical evaluation and education

of all healthcare providers who screen athletes because of the marked heterogeneity in the design and content of preparticipation cardiovascular screening and variable experience of healthcare screeners at the time. Routine diagnostic tests (ie, a 12-lead ECG) as part of the screening procedure were excluded primarily for cost-efficacy considerations. In the 2007 update,<sup>3</sup> recently published in *Circulation*, the 12-point recommendations listed in Table 1 remain unchanged and do not include universal 12-lead ECG recordings as part of every preparticipation history and physical examination, unless, of course, the athlete fails the 12-point examination.<sup>3</sup> The European Society of Cardiology (ESC) and the International Olympic Committee (IOC) screening questionnaires serve a purpose similar to that of the 12-point AHA questionnaire, although they include more questions and the content is slightly different<sup>4</sup> (Table 2). However, the prescreening strategy of the ESC and IOC differs significantly from the American approach in that universal 12-lead rest ECGs are recommended for athletes <35 years, leading to an important controversy between the American and European positions on the need for routine ECG recording.<sup>5</sup> The IOC-ESC consensus document published in 2004 to 2005 relied heavily on the 25-year Italian experience of systematic preparticipation screening of competitive athletes.<sup>4-8</sup>

The opinions expressed in this article are not necessarily those of the editors or of the American Heart Association.

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**TABLE 1. 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 50 y of age resulting from heart disease in $\geq 1$ relative
7. Disability from heart disease in a close relative <50 y 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)§

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\*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.

### The Italian Experience

In 1971, the Italian government passed a law to provide medical protection for athletes participating in organized competitive athletic events. In 1982, the law was revised to stipulate that preparticipation screening include, at a minimum, a general physical examination, 12-lead ECG, and submaximal exercise test and that the screening protocol be conducted annually.<sup>8</sup> Under Italian law, it is the responsibility of the examining physician to determine, with a reasonable degree of medical certainty, whether a particular athlete is free of cardiovascular abnormalities that could increase risk during participation in athletic training and competition. In 2006, Corrado and colleagues<sup>6</sup> reported the Italian experience using the screening process in subjects 12 to 35 years of age. The annual incidence of sudden cardiac death in athletes decreased from 3.6 deaths per 100 000 person-years (1 death per year per 27 777 athletes) in 1979 to 1981 to 0.4 deaths per 100 000 person-years (1 death per year per 250 000 athletes) in 2003 to 2004, an 89% reduction. No change occurred in the mortality rates among the unscreened nonathletic population.

**TABLE 2. Sudden Cardiovascular Death in Sports for All Participants at the Beginning of Competitive Activities Until 35 Years of Age**

Medical History
Personal History:
Have you ever fainted or passed out when exercising?
Do you ever have chest tightness?
Does running ever cause chest tightness?
Have you ever had chest tightness, cough, or wheezing that made it difficult for you to perform in sports?
Have you ever been treated/hospitalized for asthma?
Have you ever had a seizure?
Have you ever been told you have epilepsy?
Have you ever been told to give up sports because of health problems?
Have you ever been told you have high blood pressure?
Have you ever been told you have high cholesterol?
Do you have trouble breathing or do you cough during or after activity?
Have you ever been dizzy during or after exercise?
Have you ever had chest pain during or after exercise?
Do you have or have you ever had racing of your heart or skipped heartbeats?
Do you get tired more quickly than your friends do during exercise?
Have you ever been told you have a heart murmur?
Have you ever been told you have a heart arrhythmia?
Do you have any other history of heart problems?
Have you had a severe viral infection (eg, myocarditis or mononucleosis) within the last month?
Have you ever been told you had rheumatic fever?
Do you have any allergies?
Are you taking any medications at the present time?
Have you routinely taken any medication in the past 2 y?
Family history:
Has anyone in your family <50 y of age
Died suddenly and unexpectedly?
Been treated for recurrent fainting?
Had unexplained seizure problems?
Had unexplained drowning while swimming?
Had unexplained car accident?
Had heart transplantation?
Had pacemaker or defibrillator implanted?
Been treated for irregular heart beat?
Had heart surgery?
Has anyone in your family experienced sudden infant death (cot death)?
Has anyone in your family been told they have Marfan syndrome?
Physical examination
General
Radial and femoral pulses
Marfan stigmata
Cardiac auscultation
Rate/rhythm
Murmur: systolic/diastolic
Systolic click
Blood pressure
Diagnostic tests
12-lead resting ECG (after the onset of puberty)

From the ESC and the IOC Meeting on Sudden Cardiovascular Death in Sport, Lausanne, Switzerland, December 9 to 10, 2004; Lausanne recommendations adopted.<sup>4</sup>



Of the 42 386 screened athletes, 3914 (9%) required additional cardiovascular testing, and 879 (2%) were ultimately prohibited from athletic participation. The progressive reduction in mortality with implementation of more aggressive screening that includes routine 12-lead ECG recordings may lead to the conclusion that this screening approach should be applied universally in all countries. However, there are important limitations in the Corrado report, as pointed out by Thompson and Levine in a thoughtful accompanying editorial.<sup>9</sup> The study was a population-based observational report and not a temporally controlled comparison of screening versus nonscreening in athletes; a separate analysis of the routine use of ECGs compared with more limited screening in identifying athletes at increased risk is not provided; the annual death rate before the initiation of the program was 1 per year per 27 000 athletes, which is relatively high compared with other studies; and the lowest annual death rate achieved with screening was 0.4 deaths per 100 000 person-years. These rates are similar to the 0.44 sudden deaths per 100 000 person-years reported for high school and college athletes in the United States from 1983 to 1993.<sup>10</sup> In addition, the event rates in the Italian study included all events, not those that occurred only with exertion.

### The Japanese Experience

In 1973, a national screening system for cardiovascular diseases was introduced in Japan for all 1st, 7th, and 10th grade students. The primary screening process includes a questionnaire and an ECG for all students, regardless of athletic participation. Tanaka et al<sup>11</sup> reported results in 68 503 young adolescents entering seventh grade in Kagoshima who underwent primary screening. During the study period, 30 696 moved out of the area in the 10th grade, leaving a total of 37 807 students available for serial analysis and follow-up for 6 consecutive years. At the 7th and 10th grades, 975 and 901 students (2.7%) failed the primary screening and had secondary screening by physical examination, exercise tests, or echocardiography. During follow-up, 3 sudden deaths occurred in boys without syncope or family history of cardiac disease. Among the 3 deaths, one 14-year-old boy had hypertrophic cardiomyopathy identified during screening and died while jogging. The remaining 2 students, 13 and 16 years of age, died during handball and basketball, respectively. Both had a normal ECG and no autopsy, illustrating the difficulty in identifying the rare young athletes at increased risk of sudden death during competition even with ECG screening. In this series of high school students, the risk of sudden death averaged 1.32 per 100 000 per year.

### Population Differences and Disease Prevalence Rates

An issue in generalizing the findings observed in other countries to the United States is the comparability of the populations. Genetic and age differences can result in variable phenotypic expression and detectable disease rates in

different studies and populations. In the Veneto region of Italy, hypertrophic cardiomyopathy accounted for only 2% of sudden deaths among athletes from 1979 to 1996.<sup>7</sup> Arrhythmogenic right ventricular dysplasia accounted for 22% of the deaths, followed by coronary atherosclerosis in 18% and coronary anomalies in 12% of cases. Most of the 49 deaths (90%) occurred in men, a finding observed in most series. In contrast, in the United States, the single most common cause of death in young athletes participating in competitive sports is hypertrophic cardiomyopathy (approximately one third of the deaths), followed by coronary artery anomalies.<sup>3</sup> The United States has a diverse ethnic population; for example, blacks represented  $\approx 12\%$  to  $\approx 13\%$  of the US population in 2001. Young blacks account for  $>50\%$  of the high school and college student athletic field deaths resulting from hypertrophic cardiomyopathy and have a relatively high prevalence of early repolarization changes and a relatively high maximal ventricular septal thickness on echocardiography that make it difficult to distinguish an athletic heart from mild anatomic expressions of nonobstructive hypertrophic cardiomyopathy.<sup>12–15</sup>

Unsuspected cardiovascular disease is estimated to be present in 0.3% of the general athlete population in the United States. The detection of some types of cardiovascular disease does not mean that sudden death will occur with exercise. Although it is difficult to estimate the precise incidence rate of sudden death in young athletes, a Minnesota study of 1.4 million high school student-athlete participants in 27 sports over 12 years reported a rate of 1:200 000 per year (3 deaths).<sup>10</sup> In other reports summarized in a recent AHA update, the sudden rates are even smaller, less than the postscreening rates published by Corrado et al.<sup>16</sup> It would be very difficult for the 12-lead resting ECG to separate out low- and high-risk subjects at risk of sudden death during competitive activities with sufficient diagnostic accuracy, even if resources were sufficient to provide universal ECG recordings as part of preparticipation screening.

### Routine ECG Recordings in Young Athletes

The attraction of adding a rest 12-lead ECG to the screening process is the potential to detect conditions associated with exercise-induced cardiac arrhythmias and sudden death. In 1 retrospective analysis of 134 high school and collegiate athletes who died suddenly, only 3% of the examined athletes had abnormalities suspected by a standard history and physical.<sup>15</sup> Abnormal ECGs are common in some conditions such as hypertrophic cardiomyopathy (in which as many as 90% of ECGs are abnormal) and in myocarditis, arrhythmogenic right ventricular dysplasia, long- and short-QT syndrome, congenital atrioventricular block, Brugada syndrome, and preexcitation syndrome. Other conditions associated with sudden death during exertion such as Marfan syndrome, coronary artery anomalies, or catecholamine-induced ventricular tachycardia might not be detected with a resting ECG. Table 3 lists the ECG criteria for an abnormal response proposed by the ESC.<sup>5</sup> These criteria have not been tested

**TABLE 3. Criteria for a Positive 12-Lead ECG**

<b>P wave</b>
Left atrial enlargement: negative portion of the P wave in lead $V_1 \geq 0.1$ mV in depth and $\geq 0.04$ s in duration
Right atrial enlargement: peaked P wave in leads II and III or $V_1 \geq 0.25$ mV in amplitude
<b>QRS complex</b>
Frontal plane axis deviation: right $\geq 120^\circ$ or left $-30^\circ$ to $-90^\circ$
Increased voltage: amplitude of R or S wave in a standard lead $\geq 2$ mV, S wave in lead $V_1$ or $V_2 \geq 3$ mV, or R wave in lead $V_5$ or $V_6 \geq 3$ mV
Abnormal Q waves $\geq 0.04$ s in duration or $\geq 25\%$ of the height of the ensuing R wave or QS pattern in $\geq 2$ leads
Right or left bundle-branch block with QRS duration $\geq 0.12$ s
R or R' wave in lead $V_1 \geq 0.5$ mV in amplitude and R/S ratio $\geq 1$
<b>ST segment, T waves, and QT interval</b>
ST-segment depression or T-wave flattening or inversion in $\geq 2$ leads
Prolongation of heart rate-corrected QT interval $>0.44$ s in males and $>0.46$ s in females
<b>Rhythm and conduction abnormalities</b>
Premature ventricular beats or more severe ventricular arrhythmias
Supraventricular tachycardias, atrial flutter, or atrial fibrillation
Short PR interval ( $<0.12$ s) with or without delta wave
Sinus bradycardia with resting heart rate $\leq 40$ bpm*
First- (PR $\geq 0.21$ s†), second-, or third-degree atrioventricular block

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\*Increasing  $<100$  bpm during limited exercise test.

†Not shortening with hyperventilation or limited exercise test.

prospectively to determine the incremental value in identifying athletes at increased risk of sudden death during competition, and some criteria are relatively common in a normal population such as increased voltage, T-wave flattening in 2 leads, or even a slightly prolonged QTc interval.<sup>17,18</sup> ECG abnormalities are more common in athletes and may be due to cardiac remodeling from training effects.<sup>14</sup> Maron and colleagues<sup>19</sup> prospectively screened 501 intercollegiate competitive athletes at the University of Maryland using a process that included a baseline 12-lead ECG. Of the 501 subjects, 102 (20%) had at least 1 abnormality, and 13% had an abnormal ECG. Of 83 athletes with alterations on 1 study alone, 57 (69%) occurred because of the ECG, 16 (19%) were detected on the physical examination, and 10 (12%) had an abnormal history. The greater frequency of abnormal ECG responses compared with the history and physical has been reported by others.<sup>20</sup> Thus, one would anticipate a high rate of false-positive results if routine ECGs were added to clinical screening as a preparticipation requirement for competitive athletics from bayesian principles.

### Cost Efficacy

Several studies have proposed that adding an ECG to the screening process is cost-effective.<sup>11,21</sup> In 1 report, Fuller<sup>21</sup>

reported that the ECG was the most cost-effective modality in terms of approximate costs per year of life ( $\approx \$44\,000$ ) saved for a high school athlete participating in sports activities compared with a history and physical examination or echocardiogram, assuming a risk of sudden death of 1 per 100 000 per year.<sup>21</sup> This risk is twice that actually observed in the Minnesota experience and is significantly greater than that reported in US population by others.<sup>10,16</sup> The cost-effectiveness of universal ECG screening was calculated in the 2007 AHA Update with a different set of assumptions, resulting in an estimate of \$330 000 to completely screen each athlete for suspected relevant cardiac disease. The annual cost of a mass screening program that includes a prescreening ECG was estimated at \$2 billion each year in the 2007 AHA report.<sup>3</sup>

### Conclusions

It is of interest that the medical screening program in Italy, a country with a population 19% that of United States, has been in place for  $>20$  years but has not been implemented completely because of the magnitude of the medical screening requirements and the lack of adequate financial support.<sup>8</sup> The United States comprises  $\approx 25\,000\,000$  competitive athletes involved in a network of sporting activities and 10 000 000 high school and college athletes. The strategy of adding a more detailed specific questionnaire to identify the extremely rare high school or college athlete in the United States at risk of exercise-related death is prudent but requires prospective testing. More research is needed into the type of questionnaire/physical examination needed for athletes of both genders and of different ethnic backgrounds and for different types and intensities of physical activity to optimize the detection of high-risk individuals. For example, the risk of exertional sudden death is greatest for sports like football and basketball and is uncommon in young female athletes of any race compared with men, occurring in a ratio of 1:9. The risk of exercise-related death in young women is 1 per 769 000 in 1 US series and includes all sports-related nontraumatic events, not just cardiovascular, far less than the event rates reported by Corrado et al<sup>6</sup> and Van Camp et al<sup>10</sup> with ECG screening. Adding universal 12-lead resting ECG screening to this large segment of the US population when the strategy has not been sufficiently tested does not make sense unless prospective studies demonstrate that doing so reduces exercise-related acute cardiovascular events in a cost-effective way. Trying to identify the extremely rare young athlete at risk of nontraumatic sudden death during sports activities removes resources from the healthcare system in the United States and abroad that could be allocated to other urgent healthcare needs that are present in a much greater percentage of high school and college age students, such as the escalating risks of obesity, diabetes mellitus, and other conditions that reduce long-term life expectancy in this age group.



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## Disclosures

None.

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## Response to Chaitman

*Robert J. Myerburg, MD, and Victoria L. Vetter, MD*

Willingness to reconsider and amend a course of action on the basis of evolving information and current circumstances is a reflection of wisdom and strength and leads to coherent policy recommendations. Applying this principle to the question of ECG screening of young athletes leads to the conclusion that a rational basis exists for the American Heart Association (AHA) to reconsider its position on this issue. In his analysis of the currently held position of the AHA, Dr Chaitman accurately summarizes the information relied on by the authors of the AHA 2007 Update to arrive at their position. He supports their conclusions but does not explore beyond the largely historical considerations. We believe the multiple factors cited in our article, based on current and forward-looking considerations, support our position that the AHA should amend its recommendation. Among the reasons for our conclusion are the following:

- It is undisputed that a high percentage of athletes at risk for sudden cardiac arrest (SCA) can be identified or suspected from a screening ECG.
- The differences in causes of SCA among athletes in Italy and the United States actually support the strategy of ECG screening in the United States because the most common cause in the United States, hypertrophic cardiomyopathy, is more reliably identified by an ECG than is the most common cause in the Italian study, and such deaths are unevenly distributed among specific segments of the heterogeneous US population.
- ECGs can often distinguish normal athletic heart from hypertrophic cardiomyopathy.
- It is agreed that better standards for “normal” are needed, but they will not emerge from a prohibitive posture, inhibiting large-scale use of this screening strategy.
- Although the ECG is not perfect, it is intended only as the first line in the screening process. It is not claimed to be absolutely “diagnostic.” Moreover, conditions that the ECG cannot identify (coronary artery anomalies or catecholaminergic polymorphic ventricular tachycardia) cannot be identified by the currently recommended screening.
- The fact that the current AHA 12-element system has not been effective in identifying those at risk for SCA is another argument for addition of ECGs.
- SCA is likely more common than was recognized in the articles cited, and a high proportion of sudden cardiac deaths occur as the first clinical expression of a disorder.
- Many more years of life are gained by saving an adolescent with most of the conditions responsible for sudden cardiac death than would be saved by screening strategies that target older populations.
- Identifying an athlete with a genetically based SCA condition may serve many others in the family. This is not just about preventing death on the athletic field.
- From a cost-benefit perspective, a realistic estimate of cost for such a program is far below what we spend on other cardiovascular initiatives with no better payback in terms of efficacy and efficiency of preventive strategies.

Dr Chaitman’s statement on investments in other predictors of cardiovascular disease that are sorely in need of additional funding is absolutely on target. However, this is simply a reflection of the general fact that support for preventive medicine and research into individual risk profiling in the United States is far below what a country of its wealth should be placing into such efforts. It is not for the scientific, clinical, and organizational communities to prioritize health dollars but rather to indicate what is needed and provide the supporting arguments. The decision to spend money on preventing some finite number of potentially avoidable deaths in adolescents and young adults is a priority determination that belongs in the hands of the public. Ask any parent.



## *Electrocardiograms Should Be Included in Preparticipation Screening of Athletes*

Robert J. Myerburg, MD; Victoria L. Vetter, MD

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.<sup>1,2</sup> Competitive athletes included within this population subgroup are at higher risk of SCA than expected for the general population in this age category.<sup>3–5</sup> 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)<sup>6</sup> and the International Olympic Committee (IOC)<sup>7</sup> 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.<sup>8</sup> 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.<sup>8</sup> This position is retained despite various sources of data supporting an incremental benefit attributable to routine ECG screening.<sup>9</sup> 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.

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### Response by Chaitman p 2626

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#### 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.<sup>10</sup> 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  $\geq 35$  years of age.<sup>11</sup> 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

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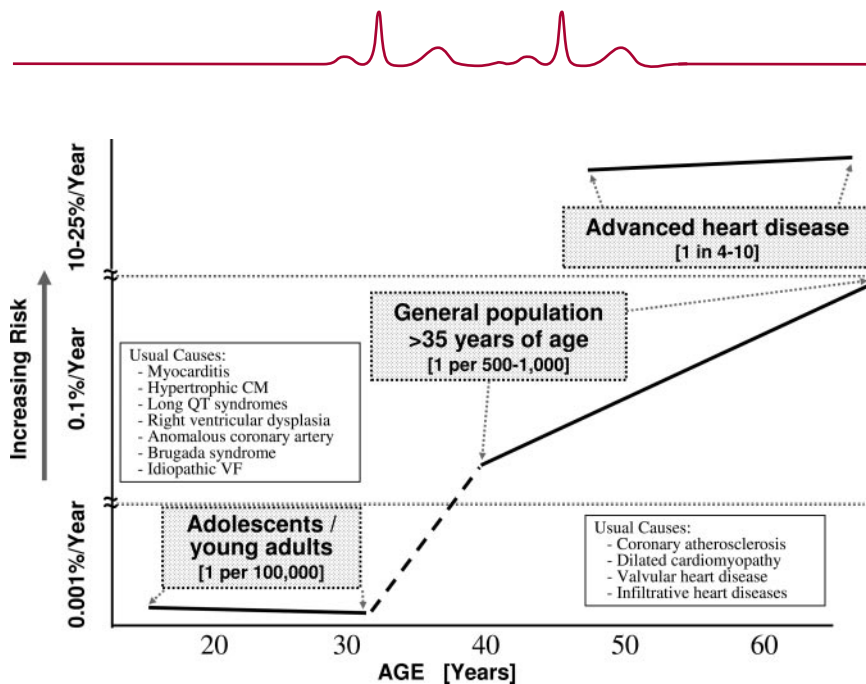
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**Figure 1.** Age-related and disease-specific risk for SCD. For the general population  $\geq 35$  years of age, SCD risk is 0.1% to 0.2% per year (1 per 500 to 1000 population). Among adolescents and young adults, the risk is 1 per 100 000 population or 0.001% per year. In the adolescent–young adult group, the risk is higher at the younger end of the range because of enhanced expression of inherited disorders after puberty. Modified from Myerburg and Castellanos,<sup>10</sup> with permission from the publisher. Copyright © Elsevier, 2004.

1% of that in middle age and older age groups (ie,  $\approx 1$  per 100 000 population) (Figure 1, bottom curve).<sup>10</sup> 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.<sup>12</sup> 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.<sup>13</sup> 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<sup>13,14</sup> 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

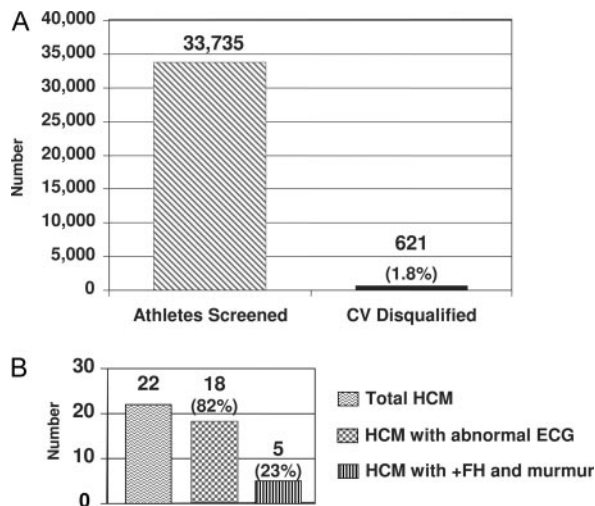
Recognition of the problem of SCD risk among adolescents and young adults (with particular emphasis on competitive athletes), followed by recommendations, guidelines, and requirements for the preparticipation cardiovascular screen-

ing of competitive athletes, has evolved over  $>30$  years. The earliest studies in the late 1970s and 1980s addressed recognition of the problem and identification of causes, followed in the 1990s and 2000s by recommendations and guidelines for participation of athletes with recognized cardiovascular abnormalities.<sup>15,16</sup> These were followed by statements about recommendations for cardiovascular components of preparticipation screening intended to identify undiagnosed cardiac disorders. Before this evolution, development and use of screening techniques were targeted largely to high school athletes and were based on local preferences, with emphasis on noncardiovascular components of screening.

The first large initiative for mandatory mass ECG screening in children began in Japan in 1973.<sup>17</sup> In this program, children in grades 1, 7, and 10 have screening for cardiovascular disease that includes a history, physical examination, and ECG. The greater sensitivity of ECG screening compared with history and physical examination has been documented in studies of Japanese school children, with the ECG making an independent contribution to sensitivity.<sup>18</sup> High-risk conditions identified include long-QT syndrome, hypertrophic cardiomyopathy (HCM), primary pulmonary hypertension, Wolff-Parkinson-White syndrome, and dilated left ventricle.

In the late 1970s, a state-subsidized national program in Italy (Medical Protection of Athletes Act) mandated annual medical clearance of all individuals 12 to 35 years of age who participated in organized team or individual sports.<sup>4</sup> Screening includes a medical history, physical examination, and ECG. From this program, Corrado et al<sup>4</sup> reported on 33 735 athletes  $<35$  years of age who were screened between 1979 and 1996. As shown in Figure 2, a total of 621 athletes (1.8%) were disqualified from competition because of cardiovascular conditions. Although the most common diagnoses leading to cardiovascular disqualifications were rhythm and conduction abnormalities (38%), 22 athletes (4%) had HCM, 21% had valvular disease, 10% had other cardiomyopathies, and 27%





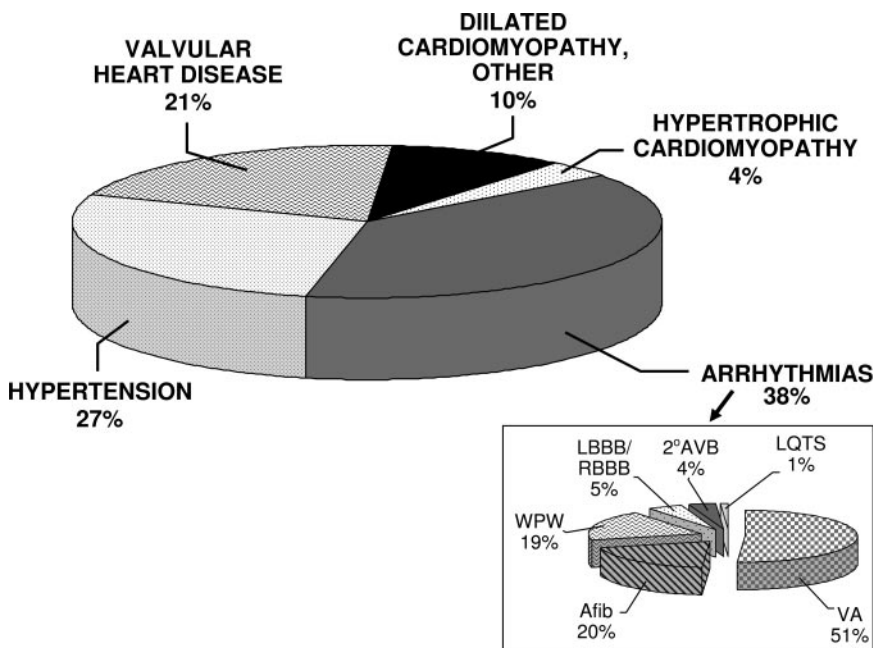
**Figure 2.** Italian athlete screening program disqualifications. A, Among 33 735 athletes screened, 621 or 1.8% were disqualified for cardiovascular (CV) reasons. B, Of 22 patients with a diagnosis of HCM, 18 (82%) had an abnormal ECG, whereas only 5 (23%) had a positive family history (FH) or cardiac murmur. Modified from Corrado et al<sup>4</sup> with permission of the publisher. Copyright © 1998, American Medical Association.

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.<sup>19</sup> 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

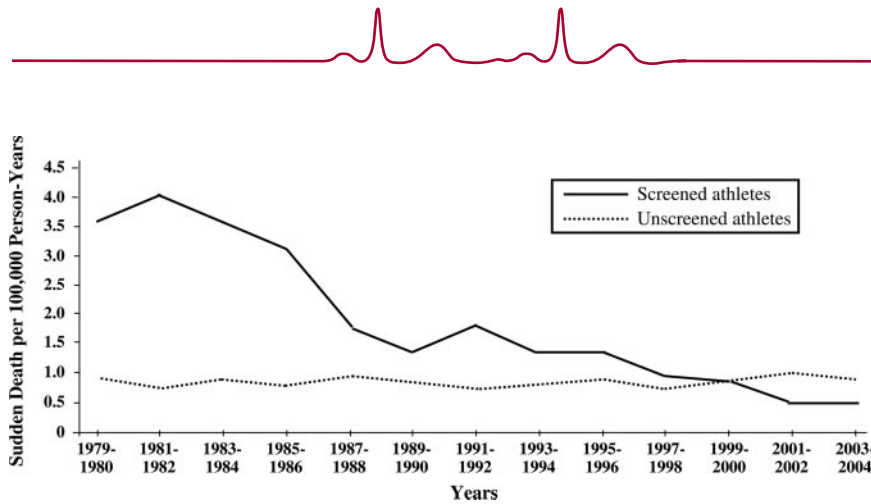
annual incidence of SCA in athletes decreased by 89%, indicating that the incidence of SCA in athletes, especially from cardiomyopathies, during the period of this screening program had significantly decreased (Figure 4).<sup>9</sup>

Considering the Italian data, the IOC recommended including an ECG in the preparticipation screening of Olympic athletes in 2004,<sup>7</sup> and the ESC followed suit in 2005.<sup>6</sup> The US Olympic Committee continues to follow the 1996/2007 AHA recommendations,<sup>8,20</sup> 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 3.** Cardiovascular disqualifications in large screened athlete population. 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<sup>4</sup> with permission of the publisher. Copyright © 1998, American Medical Association.



**Figure 4.** Annual incidence rates of cardiovascular death in screened competitive athletes and unscreened nonathletes, 12 to 35 years of age, in the Veneto region of Italy (1979–2004). Annual incidence of SCD decreased 89% in screened athletes over the time period ( $P < 0.001$ ). Unscreened nonathletes did not show a decrease in SCD over time. Modified from Corrado et al<sup>9</sup> with permission of the publisher. Copyright © 2006, American Medical Association.

undertaken in the United States. The largest reported was a study of 5615 young athletes in Nevada, which showed that the sensitivity of the ECG in identifying serious cardiovascular abnormalities was 70% compared with 3% for the history and physical examination alone.<sup>21</sup> The specificity of the ECG was 97.4%. Overall, only 0.4% of high school athletes (22 of 5615) in this study were disqualified from competition; all of those disqualified had cardiovascular abnormalities that precluded participation on the basis of the Bethesda Conference guidelines for sports participation. A limited number of community and individual school screenings in the United States have included ECGs and/or echocardiography as part of the preparticipation evaluation, generally organized by private individuals or foundations, parent groups, hospitals or physicians, industry, or other nonprofit or volunteer groups.

### 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 al<sup>22</sup> 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.<sup>22</sup> 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.<sup>15,16,23</sup> Some colleges offer screening beyond the AHA-recommended history and physical examination,<sup>8</sup> 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,<sup>24,25</sup> 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.<sup>25,26</sup> A more recent evaluation in 2005 suggested that >80% were adequate.<sup>27</sup>

Furthermore, concerns have been raised over the low sensitivity and cost-effectiveness of the preparticipation history and physical examination.<sup>28</sup> In fact, Maron<sup>29</sup> 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)<sup>30</sup> 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,<sup>4,31</sup> and Maron's<sup>32</sup> review of HCM in 2002 stated that the ECG was abnormal in 95% of these patients. In addition, Panza and Maron<sup>33</sup> and others<sup>34</sup> 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.<sup>4</sup>

Among the other cases of SCA in this age group, 80% of patients with arrhythmogenic right ventricular dysplasia have ECG abnormalities,<sup>35–37</sup> 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 al<sup>38</sup> 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.<sup>39</sup> Revision of these standards for the young population, including variations by age, gender, ethnicity, and race, as well as

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

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

Modified from Pelliccia et al.<sup>42</sup>

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.<sup>40</sup> 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).<sup>40</sup> 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.<sup>2</sup>

More pronounced abnormalities are to be expected in the more elite athletes, as has been reported.<sup>41</sup> 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.<sup>40,42</sup> 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



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.

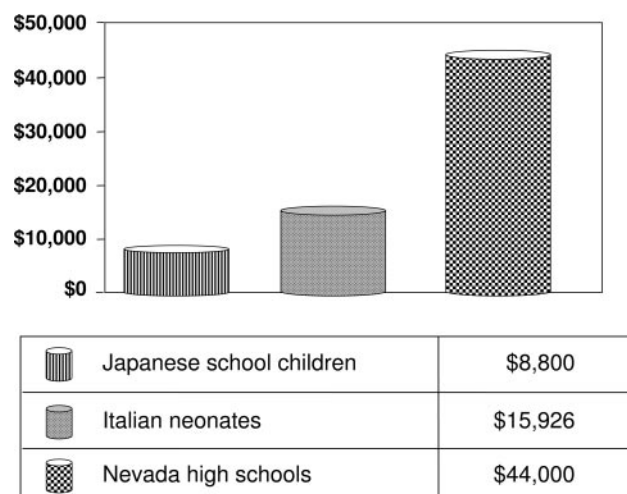
The implementation of desirable new programs that have a merit for society has been dealt with many times throughout medical history, with the absence of an infrastructure overcome by determined program development. In the case of ECG screening, a method analogous to universal deployment of automated 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).<sup>43</sup> 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



**Figure 5.** ECG cost-effectiveness. The chart demonstrates the relative cost-effectiveness of currently active ECG screening programs in Italy and Japan. All fall below the US standard of \$50 000. Based on data from Fuller,<sup>28</sup> Tanaka et al,<sup>44</sup> and Quaglini et al.<sup>45</sup>

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.<sup>28</sup> 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.<sup>28</sup> 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.<sup>4</sup> The cost-effectiveness of the screening program in Japan was estimated at \$8800 per year of life saved.<sup>44</sup>

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).<sup>28,44,45</sup> 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 defects identified, adding to the cost-effectiveness of ECG screening.<sup>44,46</sup>

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.<sup>23</sup> 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 al<sup>22</sup> 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 interventional strategies in cardiovascular medicine are based on risk reduction, with an expectation of residual risk.<sup>47</sup> 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.<sup>48,49</sup> 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.<sup>50</sup> 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 Guidelines<sup>16</sup> and the AHA recreational sports guidelines for cardiovascular genetic condition can serve as general guidelines, but the specific schools will have their own policies.<sup>51</sup>



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.<sup>40,42,52,53</sup> 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.<sup>9</sup> 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.<sup>54,55</sup>

### 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-



edge base in this area. It is appropriate to discuss challenges to implementation, but it is irrational to use them as a basis for discounting the value of ECG screening. The committee is a respected group of scientists, clinicians, and other interested parties who should be a voice for science and medicine and advocates for preventive cardiology. Implementation should be in the hands of healthcare policy makers and program developers, with their initiative based on the balance between the medical community's support of the value of ECG screening and a public policy mandate for preserving young lives.

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### Disclosures

None.

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## 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.

## An Electrocardiogram Should Not Be Included in Routine Preparticipation Screening of Young Athletes

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