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CONFERENCE REPORT

Protecting the Heart of the American Athlete

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ABSTRACT

Despite the documented health benefits of physical exercise, there is a paradoxical, but small, risk of sudden cardiac arrest (SCA) and/or death (SCD) associated with exercise. Cardiovascular causes account for 75% of sport-related deaths in young athletes, with SCA/SCD rates varying according to athlete age, gender, intensity of activity, race, and ethnicity. True risk for American athletes is difficult to assess owing to the lack of a national registry with well-defined numerators and denominators, and a consensus on metrics. Although exercise-related syncope and/or chest pain are considered the most ominous prodromal complaints, the true predictive value of symptoms is not known in athletic populations. The comparative effectiveness of various screening methodologies (e.g. history and physical alone versus history and physical plus electrocardiogram) with regard to athlete outcomes has not been determined. To address these issues in American athletes, and to coordinate a nation-wide multidisciplinary approach to athlete cardiovascular care, the American College of Cardiology Sports and Exercise Cardiology Section convened the "Think Tank to Protect the Heart of the American Athlete and Exercising Individual" on October 18, 2012, in Washington, DC. Think Tank participants (representing athletic trainers; primary care professional societies; cardiovascular specialty, subspecialty, and imaging societies; government agencies; industry; sports governing bodies; and patient advocacy groups) identified 92 quality gaps, and created an action plan to address the most urgent of these gaps: 1) Defining sports cardiology outcome metrics and conducting high-quality epidemiologic research; 2) Educating providers in the optimal use of existing clinical athlete cardiovascular care tools; 3) Promoting and conducting research to define normative values for cardiac tests in large numbers of American athletes and developing data-driven management algorithms; and 4) Coordinating athlete advocacy efforts by creating athlete cardiovascular care state-wide task forces. The Think Tank plans to convene every 2 years to monitor progress.

INTRODUCTION

Regular physical activity confers numerous health benefits for individuals of all ages (1-5). Current United States physical activity guidelines recommend that healthy adults accumulate 2.5 hours of moderate activity per week and children accumulate at least 60 minutes of daily physical activity, with 20-30 minutes of vigorous activity 3 days per week for both age groups (6). Although these recommendations have resulted in record numbers of Americans participating in sports and exercise in all major demographic groups (7-9), the vast majority of the U.S. population is sedentary (10).

Despite the benefits of physical exercise, there is a paradoxical, but small, risk of sudden cardiac arrest (SCA) and/or death (SCD) associated with exercise (11). Attempts to reduce the incidence of SCA/SCD by adding resting electrocardiograms (ECG) to athlete pre-participation evaluation (PPE) in the United States have led to robust debate regarding the comparative effectiveness of screening strategies with regard to outcomes (12,13). This debate has contributed to the growing discipline of sports and exercise cardiology in the United States, and to the expanding role of the cardiologist as a member of the athlete healthcare team (14).

Numerous multidisciplinary groups are addressing athlete cardiovascular care issues with the goal of improving athlete safety (14–19). Several states have introduced or passed SCA/SCD-related legislation to regulate athlete PPE screening; require automated external defibrillators (AEDs) in all schools; and/or educate parents, students, coaches and athletic staff regarding risk, symptoms, and treatment (20,21). Patient advocacy groups are promoting awareness of SCA/SCD causes and consequences in children, adolescents, and young adults (22–24), and federal funding agencies (the National Institutes of Health and Center for Disease Control and Prevention) have reviewed the subject with expert panels (25).

The American College of Cardiology (ACC) Sports and Exercise Cardiology Section convened the "Think Tank to Protect the Heart of the American Athlete and Exercising Individual" on October 18, 2012, in Washington, DC. Its purpose was to bring together a broad range of stakeholders who provide cardiovascular care to American athletes, to identify quality gaps in existing care, and to create specific, multidisciplinary solutions to improve care. "Think Tank" participants represented athletic trainers; primary care professional societies; cardiovascular specialty, subspecialty, and imaging societies; government agencies; industry; sports governing bodies; and patient advocacy groups. Through interactive discussions regarding risks to athletes, the meaning of symptoms, and primary and secondary prevention of SCA/SCD in athletes, the work group identified 92 quality gaps in four major domains: 1) Quantifying risks to American athletes; 2) Education, and optimal use of existing clinical athlete care tools; 3) Research, quality, and science; and 4) Advocacy and communications. Once these gaps were identified, Think Tank organizers prioritized gaps depending on their level of urgency and, over the next year and a half, continued their dialogue, incorporated most recent research, and compiled their recommendations. This report summarizes the findings of the Think Tank participants and authors, providing a practical action plan to optimize American athlete cardiovascular health.

SECTION 1. THE AMERICAN ATHLETE AND RISKS OF PARTICIPATION

There is no universally accepted definition of an athlete. Merriam Webster defines an athlete as "a person who is trained or skilled in exercises, sports, or games requiring physical strength, agility, or stamina" (26). The ACCF 36th Bethesda Conference definition adds the concepts of regular competition against others and organized programs, which is more easily applied to high school, college, professional teams, and masters athletes but excludes those who are involved in high-level physical activity away from competition or in organized groups (15). In reality, American athletes come in all ages and sizes with differing cardiac demands and adaptations to sport depending on the combination of static and dynamic components of the activity (15,16). *For the purposes of this document, we define the American athlete as any individual who engages in routine vigorous physical exercise in the settings of competition, recreation, or occupation* (14).

Participation

Sports participation can begin by age 4 to 6 years and continue through masters competitions in the later decades of life. Over 35 million U.S. youth aged 5 to 18 years (52% of girls and 62% of boys) participate in organized team and individual sports in scholastic (40%) and non-scholastic (60%) settings (27). Within this group, approximately 7.7 million boys and girls participated in varsity program U.S. high school sports seasons in the 2011-12 academic year (27). Over 450,000 student-athletes participate in organized sports at the collegiate level in the United States (28). These numbers do not include youth athletes and young adults participating in "off the grid" activities such as backcountry skiing, snowboarding, surfing, mountaineering, cycling, and BMX biking. In addition, the number of middle-aged and older adults participating in organized sports is growing. *Running USA* tracks road race participation and found there were nearly 14 million finishers (55% of them women) in 2011, up from 5.2 million in 1991 (29), and that the number of marathoner finishers over age 55 more than doubled (from 32,500 to 76,500) between 1992 and 2008 (29).

Cardiac Development and Adaptation

Although somatotype (e.g., football linemen versus distance runners) may influence sport selection, cardiac adaptations are most affected by the cardiovascular demands of the activity. Dynamic exercise substantially increases maximum oxygen consumption, cardiac output, stroke volume, and systolic blood pressure, with an associated decrease in peripheral vascular resistance. In contrast, static exercise leads to increases in diastolic blood pressure, peripheral vascular resistance, and heart rate. Long-term adaptations to endurance training lead to cardiac remodeling secondary to both volume flow and increased cardiac output, whereas strength-based exercise causes a predominant pressure effect, with minimal increase in cardiac output (15,30).

The heart grows as a child grows in physical stature, with accelerated cardiac growth through puberty (31). The heart is a muscle and responds to exercise loads with left ventricular hypertrophy. As is the case with skeletal muscle, the heart muscle's thickness can decrease with detraining. Children can participate in physical training and show improvements in VO_2max, but changes are generally modest and are influenced by age, onset of puberty, and type of training (32). Absolute VO_2max values (l/kg) also increase with growth to age 18 in boys and to age 14 in girls (33). Relative to adults, at any level of VO_2max, children have a higher heart rate and arteriovenous oxygen extraction, and lower systolic and diastolic blood pressure, stroke volume, cardiac output, and anaerobic metabolism. Endurance aerobic training in children can produce a 5% to 6% increase in peak VO_2, and with high training volume plus consistent intensity of >80% maximum heart rate, peak VO_2 can rise 8%-10% (34).

Other adaptations to exercise include increased left ventricular diastolic volume, increased vagal tone, and benign arrhythmias like sinus bradycardia, first-degree atrioventricular block, and incomplete right bundle branch block. It has been speculated that long-term endurance activity (e.g., Nordic skiing) may lead to cell damage or cardiac disease (34a). Almost all studies performed in middle-aged and older endurance athletes have observed a greater risk of atrial fibrillation for these athletes than for non-athlete controls (35,35a). Interested readers are referred to these excellent reviews on this subject (35,35a). Similarly, recent studies of athletes following intense endurance exercise have shown an acute increase in troponin and B-natriuretic peptide (BNP) levels (36). This acute myocardial damage could lead to subsequent fibrotic remodeling of the ventricular myocardium that may act as a substrate for fatal arrhythmias (37). Given the complexities of the heart response to exercise, it is clear that defining normative data for the wide range of American athletes participating in all types of sports is paramount.

Risk of SCD

SCD risk increases with physical activity intensity and is greatest in sedentary individuals during exercise (38). Exercise-associated SCA/SCD is arbitrarily defined as occurring during or within an hour of physical activity, and although exercise-related death is rare overall, 75% of sport-related deaths in young athletes are from cardiovascular causes (39). In athletes under 35 years of age, exercise-related SCA/SCD is usually associated with structural or electrical cardiac abnormalities, including cardiomyopathies, coronary artery anomalies, channelopathies, congenital heart defects, acquired myocarditis, and genetic syndromes (39–43).

It is likely that SCA/SCD risk varies with age, gender, intensity of activity, race, and ethnicity (**Table 1**). The true risk for U.S. athletes is difficult to assess because there is neither a national registry with well-defined numerators and denominators nor consensus on metrics. Should both resuscitated SCA and SCD be included in the numerator? Should all athletes be included in both the numerator and the denominator, or only those performing sports or activity at the time of SCA/SCD? Athlete SCA/SCD can be defined as an episode occurring during or within 1 hour of exercise (44,45). However, some investigators include all athletes in a well-defined demographic in the rate equation, regardless of whether SCA/SCD occurred during sleep or exercise or while out with injury (42). Differences in methodology can produce conflicting results (**Table 1**); SCA/SCD rates may vary by as much as 50%-75%, depending on whether one uses only those athletes exercising at the time of SCA/SCD or all athletes in a defined demographic (42,45,46). Whereas the former measures the risk of exercise as a trigger, the latter may measure the risk of being an athlete. Both may be valid, given that exercise is a known trigger for SCA/SCD (38,39), whereas training adaptations and chronic effects of exercise render the athlete heart a different substrate from

TABLE 1 Reported SCD Incidence in the American General Adolescent Population and in Young Athletes

Population	Reference #	Includes Resuscitated SCA	Incidence of SCD per 100,000 Person- or Athlete-Years
General population (12-19 years of age)	Atkins, 114	Yes	6.37*
MSHSL athletes (12-19 years of age)	Roberts, 75	No	0.24†
MSHSL athletes (12-18 years of age)	Maron, 76	No	0.7‡
NCAA athletes (exercise-related)	Harmon, 42	No	1.37§
NCAA athletes	"	"	2.28‖
NCAA male athletes	"	"	3.02‖
NCAA black athletes	"	"	5.65‖
Male NCAA Division I basketball athletes	"	"	31.99‖

*All SCD in adolescents: athlete, and non-athlete, and regardless of activity. †Includes only SCDs occurring during MSHSL-sponsored game or practice. ‡Includes SCDs occurring in all MSHSL-age athletes, regardless of activity level at time of SCD. §Includes only SCDs occurring during exertion in NCAA athletes. ‖Includes all NCAA athlete SCDs, whether occurring during competition, practice, sleep, or when the athlete is off with injury.

MSHSL indicates Minnesota State High School League; NCAA, National Collegiate Athletic Association; SCA, sudden cardiac arrest; SCD, sudden cardiac death.

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that of the non-athlete (14,30). The distribution of ethnic groups varies around the country, further confounding the risk equation. Risks should be determined for the varying athletic populations; and approaches to screening should be tailored on the basis of known risks.

Refining Athlete Age and Competition Classifications

The explosion of organized sporting activities for children presents parents with a variety of activities to choose for their children, ranging from entry-level sports participation to year-round "travel teams" with training schedules and competitions that rival college sports. Youth leagues are usually classified by age and/or skill level; however, young adolescent physical maturation should be considered because not all 12 year olds are created equal. Some children have focused sports-specific goals and begin vigorous training regimens by age 10 or even younger. For children, the competitive level, age and size of participants, and training intensity all represent important variables in determining safe participation from a risk:benefit perspective.

For athlete evaluation, screening and diagnostic interventions likely need athlete-specific norms and more refined age groups than "adult" and "child" to make reasonable cardiovascular risk decisions regarding participation. It is important that data specific to a particular athlete age group, genetic predisposition, sex, or intensity level not be extrapolated to make policy decisions for other athlete groups (e.g., college data applied to high school age athletes). Suggested age groupings that likely reflect both age and intensity for the majority of the population are listed in **Table 2**.

TABLE 2 Reference Ranges Anatomy and Diagnostic Parameters Based on Age (Years) and Intensity

Child	5-11
Adolescent	
Early	12-14
High school*	15-18
College*	19-22
Young adult	23-34
Middle age adult	35-64
Aging adult	65 and beyond

*Usual ages for U.S. and college athletes. U.S. eligibility for sports ranges from ages 11 through 19 and college athletes can range up to age 25 in ice hockey and older in football.

SECTION 2. MEANING OF SYMPTOMS IN ATHLETES

Syncope and Collapse

The ultimate symptom of underlying heart disease is an episode of SCA/SCD. Studies of youth who have experienced SCA/SCD find that approximately 50% reported antecedent symptoms (47). This can vary by condition. Of those with long QT syndrome, 10%-30% present with SCA/SCD as a first symptom (48). Syncope and collapse are among the most troublesome problems and yet, no consensus or evidence-based management approach exists for athletes, and epidemiological data in this group are scant.

Risk may depend upon the setting in which syncope occurs. As a general observation, syncope or collapse that occurs during or prior to completion of an event is more likely to represent cardiac or other concerning etiologies, whereas collapse following an event, especially an endurance event, may represent a more benign etiology. In a non-athletic general population of American patients ≤18 years, symptoms occurred during activity in 65% with cardiac syncope, compared with 18% in those with vasovagal syncope (49). In a study of young European athletes, 6.2% of 7,568 athletes (mean age 16.2 ± 2.4 years) reported having had at least one syncopal episode within the preceding 5 years (50). These episodes were not related to exercise (86.7% of all episodes), occurred immediately after exercise (12.0%), or during exercise (1.3%). Although syncope occurring during exercise was rare overall (0.08% of the whole study population), underlying cardiac pathology was found in 33% of those who experienced syncope during exercise (50). Similar data have not been obtained in large numbers of American athletes.

In another European study of 33 athletes (mean age 21.4 ± 3.2 years) referred for recurrent episodes of exercise-related syncope (mean number of episodes before evaluation was 4.66 ± 1.97), 12.1% developed hypotension associated with pre-syncope during maximal exercise testing, and 22 subjects (66.6%) showed a positive response to head-up tilt testing (51). Underlying high-risk cardiac conditions were not present in this group, but recurrence of syncope was common over the follow-up period. All studies considered, the widely held belief that syncope during exercise is more likely to be of cardiac cause appears to be true. However, *recurrent* episodes of exercise related-syncope appear to be associated with a more benign course. Associated chest pain or discomfort should be considered an ominous sign.

Older studies in non-athletic populations suggest that experiencing fewer than 2 syncopal episodes or a warning ≤5 seconds is more predictive of syncope due to ventricular rhythm or atrioventricular block than to syncope arising from other causes. In contrast, prodromal palpitations, blurred vision, nausea, warmth, diaphoresis, lightheadedness, and warning lasting >5 seconds are more predictive of neurocardiogenic syncope (51a) than of syncope due to other causes. Similar data has not yet been generated in athletic populations.

In the sports medicine literature, the term "exercise-associated collapse" (EAC) has been coined to describe episodes of collapse, but not necessarily syncope with loss of consciousness (52–55). EAC is defined as acute loss of voluntary muscular tone resulting in a fall to the ground in athletes who are conscious but unable to stand or walk unaided as a result of light-headedness, faintness, and dizziness that occurs after completion of an exertional event or stopping exercise. True syncope with loss of consciousness can also occur in the setting of EAC, but EAC is associated with a rapid return of consciousness in the supine position and generally with a prolonged period of weakness or fatigue. Although the mechanism(s) for EAC are multifactorial, EAC is thought to be principally the result of transient postural hypotension caused by either lower extremity pooling of blood once the athlete stops running and the resultant overwhelming of normal autonomic compensatory mechanisms, or an inappropriate neurally mediated reflex (52–55). It has been demonstrated that collapse in marathon runners accounts for 59% of finish area medical encounters and affects 1.4% of finishers (56). Although EAC is common, cardiac syncope is part of the differential diagnosis and must be ruled out from the benign forms of EAC. Distinguishing between syncope and EAC involves a long differential and the reader is referred to comprehensive reviews on this topic (52–55).

Potential cardiac etiologies and suggested work ups are listed in **Table 3**. Although these etiologies constitute most of the life-threatening causes of syncope and collapse, heat stroke should also be considered for collapsed athletes with prolonged exposure to high temperatures and humidity. Unless the athlete passes out during monitoring, results of testing are suspect and thoughtful consideration is needed to determine the best approach and methodology to quantify risk and understand the syncopal episode. The phrase “unknown syncope” is too vague, especially when considering return to play and eligibility questions, and should be avoided. Depending on the severity and recurrence of episodes, an appropriate approach to restricting the athlete’s activities needs to be defined. For those who undergo treatment, a follow-up plan based on sport and the clinical presentation and data-driven return-to-play guidelines need to be developed.

Chest Discomfort

Among athletes <35 years, chest pain (CP) is generally non-cardiac in origin. Indeed, <5% of CP in athletes in this age group is considered cardiac (57). Gastroesophageal reflux is the most common organic cause of CP, followed by exercise-induced bronchospasm. In older athletes, cardiogenic CP is more common, accounting for approximately 16% of cases of CP, with musculoskeletal and gastrointestinal reflux accounting for 36% and 13%, respectively. (57). Differential diagnosis of cardiac causes of CP, and suggested work-ups are listed in **Table 3**. Exertional CP (e.g., angina) occurs in up to 30% of patients with hypertrophic cardiomyopathy (58) and is the most common cause of SCD in young athletes. In some patients with hypertrophic cardiomyopathy, CP may be atypical, occurring at rest or with meals (58). Aortic dissection causes acute CP and may be associated with congenital bicuspid aortic valve disease, Marfan’s syndrome, Ehlers-Danlos syndrome, cocaine abuse, and weightlifting (59). There is an exhaustive differential for CP in athletes (57).

Cardiac causes must be considered first (even if briefly) so as not to miss high-risk, potentially lethal conditions. Once cardiac CP has been excluded, more common etiologies can be explored. Although a 12-lead ECG (15 lead in children/youth) should be performed for any athlete with CP, even a “normal” ECG should be interpreted with caution. Beyond the ECG, echocardiography should be performed when cardiac CP is suspected, and interpreted according to the athlete’s sport, race, gender, age and body size. Studies looking at causes of CP in athletes are lacking; therefore, large-scale, prospective epidemiologic studies are needed to define the predictive value of CP in diagnosing underlying cardiac disease in athletes.

Palpitations

Although palpitations are not one of the 12 AHA elements (16), exercise-related palpitations are included in history form questions in the 4th PPE monograph (60). The incidence in athletes varies, from 0.3% to 70%, with palpitations from all causes being much less common in young, school-age athletes but more common in highly trained and older athletes (61). The history should focus on the timing of palpitations (day, night, while trying to go to sleep, during exercise, before an event); presence of social stressors; supplement, alcohol, recreational drug, and caffeine intake; associated symptoms, particularly syncope or near syncope (see Syncope section); a precise description of sensation, including sudden onset and/or cessation; duration of symptoms; and any family history of sudden death in relatives ≤50 years old or inheritable cardiac disease. Differential diagnosis of cardiac causes of palpitations, and suggested work ups are listed in **Table 3**.

Atrial fibrillation may be more common in competitive athletes than in the general population, particularly in those with a long-standing history of endurance sports participation (35). Return-to-play (RTP) decisions are based on symptom severity, persistence of the arrhythmia, impact on athletic performance, type and need of treatment, rate and rhythm during sports, and underlying cardiac diagnosis (15). Readers are referred to these excellent recent reviews on this subject (35,35a).

TABLE 3 Suspected Etiologies and Suggested Work-Up for Specific Symptoms in Athletes

Symptom	Possible Cardiovascular Diagnostic Imaging	Suspected Etiologies
Chest Pain	• Electrocardiogram • Echocardiogram • Chest X-ray • Exercise stress test • Cardiopulmonary exercise test • Exercise echocardiogram/nuclear imaging • Cardiac/Aortic/Pulmonary CT angiogram • Cardiac MRI • 24-hour ambulatory monitoring • Event monitor	• Anomalous coronaries • Exercise-induced bronchoconstriction • Valvular heart disease • HCM • Other cardiomyopathies: DCM, RCM, LVNC, ARVC • Ischemic heart disease • Pulmonary embolism • Aortic dissection • Peri/Myocarditis • Congenital heart disease • Arrhythmias
Syncope	• Electrocardiogram • Exercise stress test • Echocardiogram • Cardiac MRI • Cardiac CT angiogram • 24-hour ambulatory monitoring • Event monitor • Implantable loop recorder	• Cardiomyopathies: HCM, DCM, RCM, LVNC • ARVC • Valvular heart disease • Anomalous coronaries • Congenital heart disease • Brugada syndrome • Long QT syndrome • Catecholaminergic polymorphic ventricular tachycardia • Atrial and ventricular tachyarrhythmias • Ischemic heart disease
Palpitations	• Electrocardiogram • 24-hour ambulatory monitoring • Event monitor • Exercise stress test • CBC, electrolytes, TSH, plasma metanephrines	• Premature atrial and ventricular contractions • Atrial and ventricular tachyarrhythmias • AV block, 2nd or 3rd degree • Anemia • Electrolyte disturbances • Thyroid and other endocrine disorders
Dyspnea	• Echocardiogram • Cardiopulmonary exercise test • Pulmonary function test • Chest X-ray • Exercise echocardiogram • CBC, ferritin	• Anomalous coronaries • Asthma • Exercise-induced bronchoconstriction • Valvular heart disease • Cardiomyopathies • Ischemic heart disease • Pulmonary embolism • Congenital heart disease • Anemia
Fatigue	• CBC, ferritin, glucose, electrolytes, TSH • Echocardiogram • Cardiopulmonary exercise test	• Anemia • Electrolyte disturbances • Thyroid disorders • Cardiomyopathies • Valvular heart disease • Exercise-induced bronchoconstriction

ARVC indicates arrhythmogenic right ventricular dysplasia/cardiomyopathy; AV, atrioventricular; CBC, complete blood count; CT, computed tomography; DCM, dilated cardiomyopathy; HCM, hypertrophic cardiomyopathy; LVNC, left ventricular non-compaction cardiomyopathy; MRI, magnetic resonance imaging; RCM, restrictive cardiomyopathy; and TSH, thyroid stimulating hormone.

Premature ventricular contractions (PVCs) are common in athletes, but for unclear reasons. Limited data suggest that PVCs ≥2,000/24 hours are associated with a higher chance of underlying heart disease (62). Whether this is due to the PVC burden alone (63) or to true underlying structural disease is not known. If no underlying heart disease is present, RTP without restrictions with PVCs is generally safe.

Dyspnea

Dyspnea in the athlete is a common complaint, with a differential that spans a wide range of benign and serious causes (64). Assessment of dyspnea should begin with an attempt to characterize the nature and severity of the symptom: whether it is associated with a decrease in exercise capacity; episodic or predictable; severe relative to other athletes; related to changes in air temperature or humidity; occurring in the setting of wheezing; associated with rapid or slow heart rate; and whether the athlete has known cardiac and/or pulmonary abnormalities or is an older person with coronary artery disease (CAD) risk factors. After assessment of dyspnea, cardiac assessment should be performed, with ECG and echocardiography. If the athlete has a known history of cardiac disease and complaints of dyspnea, the baseline abnormality should be reassessed. Differential diagnosis of cardiac causes of dyspnea, and suggested work ups are listed in **Table 3**.

Pulmonary causes of dyspnea can be explored using pulmonary function tests at rest and, if necessary, in a setting similar to that which causes the symptoms (e.g., peak flow measures on the soccer or track field). Exercise-induced asthma is the most common cause of dyspnea in athletes (65). Asthma and vocal cord dysfunction may coexist in a given athlete (66).

New dyspnea complaints at similar exercise levels or complaints occurring at lower activity levels in an older athlete should lead to consideration of ischemic heart disease. Dyspnea relative to other athletes, once evaluated for cardiac and pulmonary causes, may be due to hormonal or metabolic causes or to lack of conditioning relative to peers. Cardiopulmonary exercise testing with gas exchange and ventilatory parameters is potentially helpful in documenting true functional capacity relative to appropriate age and fitness status.

Fatigue

Fatigue (and/or unsatisfactory athletic performance) is a common and yet nonspecific complaint; work ups in athletes can be as frustrating as workups in non-athletic populations. A balance between adequate caloric intake to maintain performance on the one hand, and obtaining and maintaining appropriate body composition on the other hand, is essential to maximize performance and avoid "overtraining" and fatigue (67). When fatigue is the only symptom, a cardiac diagnosis is exceedingly rare. This impression is based on experience, rather than known published data.

Screening of Those with Positive Family History

The majority of SCA/SCD-associated conditions in athletes ≤35 years have a genetic basis (11,16). Unfortunately, most people are not fully aware of important aspects of their family history, making screening a relatively unhelpful tool. About 16% of those with a prior SCA/SCD have a known positive family history (FHx) (47). Efforts to heighten awareness of FHx should include development of a workable definition of positive FHx, promotion that FHx be part of a general health evaluation, and instruction for patients on filling out a simple family tree. The AHA documents and the 4th PPE are not completely congruent regarding the definition of FHx (16,60).

General Considerations for Ordering and Interpreting Diagnostic Tests in Athletes

Diagnostic testing in the athlete is affected by a number of issues peculiar to the population (**Table 4**). These issues have been outlined in detail in a recent publication (14). For example, "normal" values for a given athlete may lie outside the published "non-athlete" norm (11,68). Additionally, stress testing and ambulatory monitoring require tailoring to simulate the demands of the individual athlete's sport. Athlete safety must be balanced against the risk of inappropriate testing, unnecessary exercise restriction, over-diagnosis, and inappropriate procedures. The availability of an athlete-centered knowledge base to interpret test results for athletes may help to limit the "diagnostic creep" whereby one slightly abnormal test leads to another slightly abnormal test and so on. Additionally, in the long term, testing and treatment may have a more adverse impact on an athlete's physical and psychological health than continued participation.

RTP Decision Making in the Athlete

The 36th Bethesda Conference outlined sports participation recommendations for specific cardiovascular conditions (15), but it has been criticized owing to its

TABLE 4 Pitfalls in Interpreting Cardiac Testing in Athletes

Test	Gaps
Stress test	1. Bruce protocol is designed to detect coronary artery disease, not inherited diseases. 2. Testing protocol needs to simulate conditions and demands of sport. 3. Some providers are not aware of this.
ECG	1. Lack of normative data in all groups of American athletes. 2. Can European data be extrapolated to American athletes? 3. Heterogeneity of athlete groups: one size of normative data does not fit all. 4. Does not detect anomalous coronary artery, second most common cardiac cause of SCA/SCD in athletes.
Echocardiography	1. Lack of normative data in all groups of American athletes. 2. Can European data be extrapolated to American athletes? 3. Heterogeneity of athlete groups: one size of normative data does not fit all. 4. Sensitivity for detection of anomalous coronary artery may vary according to athlete body habitus.
Ambulatory monitoring	1. Routine monitoring may not detect the problem. 2. Challenges to monitoring: contact sports, lead adherence under certain conditions, underwater sports 3. Depending on when symptoms occur, they may need to be monitored while the athlete is practicing or competing. 4. Lacking normative data in large numbers of American athletes at all levels: how much ectopy is "normal"?
MRI	1. Lack of normative data in all groups of American athletes 2. What does fibrosis mean?
CT	1. Lack of normative data in all groups of American athletes 2. How can risk of radiation be minimized? 3. Ratio of risk:benefits of MRI versus CT in athletic populations is not clearly defined.

CT indicates computed tomography; MRI, magnetic resonance imaging; SCA, sudden cardiac arrest; and SCD, sudden cardiac death.

TABLE 5 Guidelines for Sports Participation for Athletes With Known Cardiac Conditions

Guideline	Comment
AHA 2007 Update	• 12 elements are "embedded" in PPE • Does not recommend routine ECG screening
36th Bethesda Conference recommendations	• Gold standard for RTP in USA • Classifies sports by dynamic and static components
ESC Participation Recommendations	• Similar to Bethesda's but with notable differences • No participation for genotype positive-phenotype negative HCM
AHA Consensus for Young Patients with Genetic CVD	• Includes grading system for exercise • Consistent with Bethesda's • Useful for prescribing exercise for those with high risk conditions
NASPE Policy Conference on Arrhythmias and the Athlete	• Older but similar to Bethesda's
WHF, IFSM, AHA Consensus on Masters Athletes	• Similar to Bethesda's • Athletes >40 years of age • Range of conditioning from elite athletes to walk-up athletes

AHA indicates American Heart Association; ECG, electrocardiogram; ESC, European Society of Cardiology; HCM, hypertrophic cardiomyopathy; IFSM, International Federation for Sports Medicine; NASPE, North American Society for Pacing and Electrophysiology (now Heart Rhythm Society); PPE, pre-participation evaluation; RTP, return to play; and WHF, World Heart Federation. (Adapted from Oliveira [72].)

dependence on expert opinion rather than high-quality evidence (69,70). Two recent reports in athletes with implantable cardioverter defibrillators and in patients with long QT syndrome are illustrative of the type of data that needs to be generated to help elevate this expert opinion to the status of true guidelines (70,71). A strategy devised for a particular athlete, although potentially based on sound published data or even consensus "expert opinion," is complicated by knowledge gaps, medical legal issues, and mutual athlete/family input. The same holds true for all of the other main published athlete participation guidelines (**Table 5**) (72).

SECTION 3. PRIMARY AND SECONDARY PREVENTION OF SCA/SCD EPISODES IN ATHLETES

Primary Prevention

Primary prevention of SCA/SCD requires identification of a predisposing disease, and early intervention to mitigate risk. The optimal screening protocol facilitates diagnosis of individuals at risk for SCA, enables effective identification, and recommends optimal therapy strategies to improve survival without causing harm. This remains a matter of discussion related to the knowledge gaps that could guide this comprehensive goal (25).

Screening Methods and Standards in the United States

The current American Heart Association- (AHA) recommended cardiovascular screening protocol for competitive athletes uses a history and a physical exam-based PPE that includes 12 AHA elements (**Table 6**) (16). All 12 elements are incorporated into the most recent PPE monograph (4th PPE, 60), a collaborative effort of 6 national medical societies that recommends a PPE by the athlete's personal physician upon entry into sports at the high school and college levels. Mass PPE Screening (e.g., in the high school gymnasium) is highly discouraged (60,73). State legislatures, state interscholastic athletic associations, or departments of education may set specific standards and some local school districts or schools will direct their specific standards.

Compliance with the AHA recommendations is poor at the state, physician, and athletic department levels (73). The latest account found that only about 5% of states use all 12 AHA elements in their forms (74), and only 8 states utilize a form consistent with the PPE Monograph (73). Non-physician personnel such as chiropractors are currently allowed to perform PPEs in 35% of states (74). Standardization of the PPE should improve this model (16). Future efforts must address provider education and policy requirements to improve implementation of the most recent recommendations from leading national medical societies.

Outcome data for the standardized PPE in American athletes is limited. Insurance data from the Minnesota State High School League, where a comprehensive standardized PPE is performed, indicates that the death rates during competitive sports appear to be exceedingly low (0.24 per 100,000) in high school student-athletes over a 19-year period (75). Other analyses of Minnesota high school age athletes (that include all deaths in athletes in this age group) show a death rate of 0.7 per 100,000 athletes (76,77). These data appear to support that careful evaluation of high school athletes may identify some with cardiovascular warning symptoms or signs. At present, 30% to 47% of National Collegiate Athletics Association Division I programs and 14% of lower-division programs use non-invasive cardiovascular screening methods (ECG and/or echocardiogram) for either all athletes or those deemed to be high risk (78,79).

TABLE 6 The 12-Element AHA Recommendations for Preparticipation Cardiovascular Screening of Competitive Athletes

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

*Parental verification is recommended for high school and middle school athletes. †Judged not to be neurocardiogenic (vasovagal); of particular concern when related to exertion. ‡Auscultation should be performed in both supine and standing positions (or with Valsalva maneuver), specifically to identify murmurs of dynamic left ventricular outflow tract obstruction. §Preferably taken in both arms. Reproduced with permission from Maron et al. (16).

Other Screening Methods—ECG Screening

Data from the Italian screening program suggest that ECG-based screening may prevent SCD by identifying youth with undiagnosed conditions predisposing them to SCA, although those excluded from activity were not tracked for outcomes data (80). The incidence of SCD in athletes decreased from 3.5 to 0.4 per 100,000 athletes (89%) over a 25-year period. The death rate at the start of the program was high, perhaps because of the lack of appreciation of arrhythmogenic right ventricular dysplasia (ARVC), which is common in this part of Italy (81). In contrast, Israel has implemented a mandatory ECG screening program but has not reported a reduction in SCD (82). Adding an ECG to the history and physical may increase disease detection sensitivity relative to history and physical alone (83-86), but large-scale U.S. data are lacking to determine if this approach will prevent SCD, or do more harm than good compared with the currently recommended AHA standard (16). Similarly, data are lacking to show the overall effectiveness of the history and physical in identifying a majority of individuals at risk for a SCA or preventing SCD. Advanced imaging modalities for screening, such as echocardiography, may increase the sensitivity to detect a small proportion of cardiac diseases. But these modalities come with economic and logistical costs and may even provide false reassurance, especially if "limited echocardiography" is done only to exclude hypertrophic cardiomyopathy. ECG and echocardiography are useful during secondary evaluations to assess for electrical conditions, cardiomyopathy, valvular disease, or coronary anomalies, and are essential for a thorough evaluation of a symptomatic athlete.

Suggested barriers to ECG screening in the United States have traditionally included high false positive rates, false negatives, feasibility, logistics, costs, efficacy, risks of inappropriate exclusion from sports, potential anxiety associated with testing, unnecessary procedures performed either to evaluate or treat potential or asymptomatic disease, future insurability, and the risk of treatments (16).

Athlete-specific ECG interpretation criteria have the potential to decrease false positive rates and improve cost-effectiveness (87-89). Determining ECG parameters in youth according to age, gender, race and ethnicity, and sport type and intensity should improve ECG test characteristics and make some types of false positives less common (90). Recommendations of ECG criteria to improve sensitivity and specificity await validation by clinical trials (91-93). The best methods to identify those athletes at risk for SCA through primary screening are controversial, with ongoing debate regarding the addition of an ECG (12,13,94-102). Before changes in screening programs are recommended nationally, data should be acquired that can demonstrate an improved outcome in young, asymptomatic athletes and show that the benefit of screening outweighs the risks. The dilemma of disposition of the asymptomatic athlete with a condition associated with SCD also remains a key concern in this debate, regardless of how such athletes are identified.

Secondary Prevention

Because screening will neither detect all at risk nor prevent commotio cordis, SCA/SCD will continue to occur in sports. Secondary prevention of SCD requires life-saving measures when an SCA occurs. AEDs alone will not solve the problem. Coaches, staff, athletes, and bystanders should be taught to recognize SCD, perform cardiopulmonary resuscitation (CPR), and operate an AED as part of a comprehensive Emergency Action Plan (EAP).

Overview of Chain of Survival and Public Access Defibrillation

Community studies have demonstrated that public access defibrillation programs are effective in sites of high population density where emergency medical services (EMS) response may be slow, producing high survival rates in multiple venues (103-107).

Recognition of SCA

The AHA has stated that the sudden collapse of an adult should cause suspicion of a SCA (108). In healthy athletes, one may not have as strong a suspicion of a SCA. Thus there is less expectation of SCA, with delays in recognition. Seizure-like activity occurs in 30% to 40% of SCAs owing to brain anoxia, and agonal gasping respirations occur in 30% to 40%, adding to the hesitancy of a bystander to suspect SCA and act. Any collapse, even following trauma, should be considered a SCA; 911 should be called, CPR initiated, and an AED, if present, should be used with as little interruption to CPR as possible (109,110).

Areas that Determine Impact of Resuscitation

The interval between cardiac arrest and initiation of CPR is one of the prime determinants of the time to defibrillation and of survival, with survival unlikely for time intervals greater than 10 minutes to defibrillation (106). Advanced life support in the field increases the likelihood of survival in cardiac arrest, and hospital care with induced hypothermia dramatically improves prognosis (111). The new AHA guidelines support the delivery of high-quality chest compressions with minimal interruptions for both hands-only and conventional CPR. Factors including quality, depth, rate of compressions, and duration of interruptions impact the outcome of the cardiac arrest (112).

Effectiveness of AED Programs

High School Athletics

SCA in young athletes is a catastrophic event with a historically low survival rate (4% to 21%) (113–115). Data from 486 cases of exercise-related SCA in young individuals show an average survival rate of just 11% from 2000 to 2006 (113). A similar survival rate of 16% was found in 128 cases from the USA Commotio Cordis Registry (116). These results are attributable to delayed rescuer recognition of SCA, slow response times, and inadequate preparation. Early CPR and defibrillation with an AED in youth can result in a survival rate of 64% to 74% (117). A 2-year prospective study in 2,149 high schools indicated that 87% of participating schools had an onsite AED program, with 89% of students and adults who developed SCA during sports or physical activity at schools with an onsite program surviving to hospital discharge (118). The survival rate for commotio cordis in young athletes has increased to 58% in the last 6 years, largely because of increased recognition, greater availability of AEDs, and early defibrillation (119). Early defibrillation and onsite AED programs are therefore both critical and effective in maximizing survival following SCA in the athletic setting.

Intercollegiate Sports

Detailed reports of resuscitation outcomes for National Collegiate Athletic Association athletes demonstrate dismal survival rates. A report of National Collegiate Athletic Association programs found that 91% of Division I, 77% of Division II, and 81% of Division III institutions had at least one AED on site (120,121). Although an encouraging development, a comprehensive emergency action plan (EAP) should include more than onsite AEDs alone.

SCA at Schools and Athletic Events

Emergency planning and AEDs at schools and sporting venues offer the potential for effective secondary prevention of SCD. SCAs reported in schools occur primarily in adults, with only 34% occurring in children. Most were witnessed (83%) and received bystander CPR (77%). Ventricular fibrillation was the initial rhythm in 57% of patients, and 32% survived to hospital discharge (122). The frequency of SCA in adults >35 years has been reported at 1:1,000, suggesting that emergency preparations should extend beyond athlete participants (123,124).

Keys to Successful Resuscitation

Emergency Action Plans

The ability to respond to SCA depends heavily on preparation and a coordinated effort on the part of all responders. In 2004, the AHA recommended that all schools have an emergency action plan (110,125). The 2007 Inter-Association Task Force provided consensus recommendations for the management of SCA in the athletic setting, which include the need for schools to have onsite AEDs if they cannot reliably achieve an EMS call-to-shock interval of less than 5 minutes (17). Elements of an effective AED program include: 1) development of an effective communication system to alert onsite responders and activate the local EMS system; 2) coordination of the response plan among school, team, or club staff and local EMS; 3) instruction and training of potential first responders in CPR and AED use; 4) rapid availability of AEDs; and 5) practice and review of the EAP at least annually (125). Steps also should be taken to ensure appropriate device maintenance and readiness checks before sporting events. The EAP should be developed and coordinated with local EMS personnel, school public safety officials, on-site first responders, and school administrators, and reviewed with certified athletic trainers, team and attending physicians, athletic training students, school and institutional safety personnel, and coaches. EAPs should be specific to each individual athletic venue. The first responder may be a coach, strength and conditioning staff, or other institutional personnel. Involving student athletes in the EAP may improve the potential for a successful outcome, particularly if the coach is the victim.

Location of AEDs and Training of School and Athletic Staff

AEDs should be readily available and on site at the athletic venue when emergency situations arise, ensuring no more than a 2- to 3-minute turnaround from the site of potential collapse. Schools should ensure that away competitions have protection or bring a spare AED. Certification in CPR, AED, and EAP review should be required for all athletic personnel associated with practices, competitions, skills instruction, and strength and conditioning.

Funding for School/Athletic Field AEDs

Many funding sources are available, including donations by community organizations, foundations, hospitals, and individuals who have lost a family member. Once obtained, responder training, maintenance of pads, and replacement and maintenance of batteries results in additional operational costs.

AEDs in Schools

It has been estimated that on any given school day, 20% of the population will be in a school, including many adult employees, visitors and those using schools for community events, including adult education and voting.

In 2004, guidelines for treating SCA in schools suggested that a lay rescuer AED implementation program be considered in any location (e.g. school) with at least one of the following: 1) a reasonable probability of AED use within 5 years after AED placement and training of lay rescuers; 2) high-risk adults working at the school or children attending school who might be at risk for a SCA; and 3) the inability to reliably achieve a EMS call-to-shock interval of <5 minutes (110). The AHA supports state legislation and education policies and encourages each high school to have an AED and to appropriately train personnel, including athletic coaches, trainers and athletes (110). Between 30% and 70% of schools are noted to have AEDs, some donated or purchased with funds raised by parents or from foundations of parents who have lost children to SCA and many purchased at a discount with industry support (123,126–128).

Effective adoption of AEDs in schools involves the following: 1) Creation of an EAP that includes early CPR and AED; 2) Creation of an AED team in the school; 3) Integrating CPR training into the school curriculum and insuring that adequate numbers of teachers, students, administrators, and staff (including coaches, nurses, and other athletic staff) are trained in CPR and AED skills; 4) Acquiring adequate numbers of AEDs for school and athletic events, both at home and away; and 5) Consideration of access to an AED within 3 to 5 minutes. The major barriers to AED acquisition in schools include cost of purchase, cost of maintenance, and lack of time for training (129).

Student CPR/AED Education and Training

In 2003, the International Liaison Committee on Resuscitation recommended that CPR education be part of the school curriculum (129). In 2004, the AHA recommended training all teachers and students in CPR. In 2011, the AHA issued an AHA Science Advisory recommending that training in CPR and familiarization with AEDs be required elements of secondary school curricula, with guidelines for overcoming barriers (130).

A number of studies support the feasibility and efficacy of teaching CPR and AED use to school children. Such training should emphasize the recognition of SCA, the importance of calling for help or for an AED, and the delivery of high-quality chest compressions. Studies in subjects aged 4 to 20 years indicate the improvements that occur with training. Those provided instruction in practical, hands-on skills exhibit better performance skills than do those with instructional or theoretical knowledge alone. Chest compression depth correlates with physical factors such as weight and height, with studies showing that 14 year olds can perform these skills as well as can adults (131). With minimal training, 9 to 12 year olds have been shown to accurately use an AED in a time frame just slightly shorter than that expected of trained emergency medical technicians. Training by school teachers has been shown to be as effective as that performed by healthcare professionals. The most effective retention training has not been determined, but full instructor-led courses are not more effective than self-instruction and computer-based models.

In King County, WA, 52% of bystanders can perform CPR; the area's survival rate is higher than that of the rest of the United States (132). In Norway, the training of over 50,000 school children was associated with an increase in bystander CPR from 60% to 73% (133). Students with training have been shown to be more willing to perform CPR (132).

Barriers to CPR training in schools have been noted to include a lack of trained instructors, lack of time in the school curriculum, and lack of funding (132). Personal barriers noted by students that affect their willingness to use CPR or AED skills include concerns related to both poor knowledge and fear of imperfect performance (130,134). Simplification of the process by recommendation of hands-only bystander CPR may increase bystanders' willingness to use their skills.

Legal Implications of Secondary Prevention

CPR legislation has advanced rapidly since the passage of the Sudden Cardiac Arrest Act in 2000. Multiple variations of these laws exist (see **Table 7**).

SECTION 4. AN ACTION PLAN FOR PROTECTING THE HEART OF THE AMERICAN ATHLETE (TABLES 8–12)

Stakeholders

Our goal was to bring together a group of many relevant, diverse stakeholders to develop collaborative, multidisciplinary approaches to improving the cardiovascular care of American athletes of all ages. This ambitious goal

TABLE 7 Legal Implications of Secondary Prevention

Law or policy	Implication
Good Samaritan laws	All states in the US have some type of "Good Samaritan" legislative protection that protects bystanders from legal liability if AED use is attempted without "gross negligence or willful and wanton misconduct." Legal protections for owner-leaders or medical personnel are less straightforward.
CPR curricula	As of the 2009-2010 school year, content standards for CPR curricula are present in 36 states. These standards vary from recognizing the steps of CPR to full certification.
AED laws	As of 2012, 15 states had legislative mandates requiring or supporting AED placement in schools. All 50 states plus the District of Columbia have at least 1 piece of AED legislation in place.
The Josh Miller Act	The Josh Miller Act was introduced in Congress in April 2011 to establish a grant program for AEDs in elementary and secondary schools. It was referred to committee but not acted upon.

AED indicates automated external defibrillator and CPR, cardiopulmonary resuscitation.

requires an appreciation of the unique knowledge, perspective, activities, and experiences of each group.

Front-line providers—athletic trainers, school nurses, team/sports physicians, and physicians who provide coverage for events: As the inpatient care team is to hospitalized patients, these front-line providers are to relatively healthy, out-patient competitive athletes. Serving athletes at the front lines at practices and competitions, these providers are responsible for the immediate care, including AED application, of an athlete who develops symptoms (e.g., collapse, SCA). They make immediate RTP decisions and are responsible for creating and implementing all athlete healthcare policies both at local and national levels through their professional societies and sports governing bodies. These providers belong to or work closely with the American Academy of Family Physicians (AAFP), American Academy of Pediatrics (AAP), American College of Sports Medicine (ACSM), American Medical Society of Sports Medicine (AMSSM), American Orthopaedic Society for Sports Medicine (AOSSM), National Athletic Trainers Association (NATA), National Collegiate Athletic Association (NCAA), National Federation of State High School Associations, professional sports leagues (e.g., Major League Baseball, Major League Soccer, the National Football League, the National Hockey League, the National Basketball League), and the United States Olympic Committee and its collection of "sportfolios" of U.S. sports federations (e.g., U.S. Figure Skating, U.S.A. Track and Field).

Other healthcare providers and their respective professional and scientific organizations: Primary care providers (e.g., family practitioners, pediatricians, sports medicine and/or team physicians, nurse practitioners, physician assistants, cardiac care associates, cardiologists, cardiovascular subspecialists) screen and/or evaluate athletes of all ages, request and/or provide and

TABLE 8 Quantifying Risks to American Athletes

Gap(s)	Strategies and Methods	Responsible Parties	Time Frame
True cardiac risks to athletes are unknown owing to varying methodologies, incomplete assessment of risk, overlap with other causes of sudden death, and balancing risk of participation with the risk of not participating.	*Define sports cardiology metrics* 1. Convene multidisciplinary group of experts to create well-defined metrics for causes and incidence of SCA/SCD in athletes, and other major outcomes. 2. Resolve disparate definitions of numerator and denominator in SCA/SCD rate equation, and recommend how rates be reported in literature. 3. Resolve controversies over whether events are exercise related or athlete centered. 4. Arrive at consensus on other significant CV and sports cardiology outcomes (e.g., MI, arrhythmias, days missing competition or practice dissection, fibrosis).	Healthcare providers and their respective professional and scientific organizations: AAFP, AANP, AAP, AAPA, ACC, ACP, ACSM, AHA, AMSSM, AOASM, AOSSM, NATA; research scientists; funding agencies	2014-2015
	Conduct epidemiologic research 5. Once metrics are defined, develop prospective athlete outcomes registries that are sports specific and level specific and take into account athlete heterogeneity. 6. Include risks of cardiac testing/treatment and procedures in athlete registries. 7. Include risks of sedentary lifestyle.	Same as above	Ongoing

AAFP indicates American Academy of Family Physicians; AANP indicates American Association of Nurse Practitioners; AAP, American Academy of Pediatrics; AAPA, American Academy of Physician Assistants; ACC, American College of Cardiology; ACP, American College of Physicians; ACSM, American College of Sports Medicine; AHA, American Heart Association; AMSSM, American Medical Society for Sports Medicine; AOASM, American Osteopathic Academy for Sports Medicine; AOSSM, American Orthopaedic Society for Sports Medicine; CV, cardiovascular; MI, myocardial infarction; NATA, National Athletic Trainers Association; SCA, sudden cardiac arrest; and SCD, sudden cardiac death.

TABLE 9 Education, and Optimal Use of Existing Clinical Athlete Care Tools

Gap(s)	Strategies and Methods	Responsible Parties	Time Frame
Gaps in provider knowledge about athletes and about conditions that place them at risk	*Optimal implementation of existing clinical tools.* 1. Education and/or certification of providers making participation decisions (at all levels) 2. Education includes knowledge use of the 4th PPE, 12 AHA elements, 36th Bethesda Conference guidelines, and masters athletes. 3. Enhance presence of tools on AAFP, AANP, AAP, AAPA, ACC, ACP, ACSM, AHA, AMSSM, AOASM, AOSSM, and NATA Web sites. 4. Monitor knowledge and use of tools through performance improvement activities and CME.	Healthcare provider professional and scientific organizations: AAFP, AANP, AAP, AAPA, ACC, ACP, ACSM, AHA, AMSSM, AOASM, AOSSM, NATA; school nurses, athletic directors, and coaching staff	2014-2016
	Develop core competencies in sports and exercise cardiology (athlete-centered CV care). 1. Create competencies for all those involved in athlete CV care, appropriate to type of practice, in collaboration with respective professional societies and board examiners: AAFP, AANP, AAP, AAPA, ACC, ACP, ACSM, AHA, AMSSM, AOASM, AOSSM, NATA, school nurses, athletic directors, and coaching staff. 2. Include basic sports cardiology competencies in general certification exams. 3. Update competencies as new information becomes available. 4. Promote development of team-based care at local levels (ATC, team physician, school nurses, PCPs, cardiologist and cardiac subspecialists).	Same as above	2014-2017
Gaps in provider knowledge of risk mitigation strategies: hands-only CPR, recognition of SCA and its warning signs, and optimal implementation of AEDs in schools and athletic venues	*Educate on early identification of SCA, including seizures and agonal breathing.* 1. Focus education on those likely to respond first to a collapse: ATCs, school nurses, team physicians, coaches, parents, students, and teachers. 2. Incorporate identification of SCA/SCD into general proficiency examinations for providers and first responders.	Front-line providers: ATCs, school nurses, team/sports physicians, and physicians who provide coverage for events; athletic directors, and coaching staff; athletes; educators; parents; public; and media	2014-onward
	Educate on SCA warning signs and symptoms while not unnecessarily restricting athletes. 1. Focus education on those likely to respond first to a collapse: ATCs, school nurses, coaches, parents, students, and teachers. 2. Create a multidisciplinary educational tool-kit at the national level that can be used by all 50 states to educate.	Same as above plus: healthcare provider professional and scientific organizations: AAFP, AANP, AAP, AAPA, ACC, ACP, ACSM, AHA, AMSSM, AOASM, AOSSM, NATA	2014-onward
	Promote widespread knowledge of hands-only bystander CPR. 1. Convene a state-wide multidisciplinary task force to work with state DHHS and board of education to promote CPR training in required curricula for all middle school and HS students (see advocacy). 2. Create public service announcements at sporting events to promote hands-only CPR and early application of AED.	Same as above	2014-onward
	Enhance AED efforts in each state (see Advocacy).	Same as above	Ongoing

AAFP indicates American Academy of Family Physicians; AANP, American Association of Nurse Practitioners; AAP, American Academy of Pediatrics; AAPA, American Academy of Physician Assistants; ACC, American College of Cardiology; ACP, American College of Physicians; ACSM, American College of Sports Medicine; AHA, American Heart Association; AMSSM, American Medical Society for Sports Medicine; AOASM, American Osteopathic Academy for Sports Medicine; AOSSM, American Orthopaedic Society for Sports Medicine; ATC, Certified Athletic Trainer; CME, continuing medical education; CPR, cardiopulmonary resuscitation; CV, cardiovascular; MI, myocardial infarction; NATA, National Athletic Trainers Association; PCP, primary care provider; SCA, sudden cardiac arrest; and SCD, sudden cardiac death.

TABLE 10 Research, Quality, and Science

Gap(s)	Strategies and Methods	Responsible Parties	Time Frame
Predictive value of symptoms not known	*Develop evidence-based symptom management*. 1. Promote and conduct research examining the predictive value of symptoms in athletes (level and sports specific). 2. Align data among disparate groups. 3. Develop data-driven management algorithms.	Healthcare providers and their respective professional and scientific organizations; research scientists; funding agencies	2014-onward
Lack of normative data in large populations of American athletes of varying age, race, ethnicity, size, and sport	*Define norms in American athletes* 1. Review European data and determine if applicable to USA. 2. Define gaps for norms in American athletes for ECG, echocardiography, MRI, CT, ambulatory monitoring, and stress testing. 3. Close knowledge gaps through researching large numbers of American athletes (level and sports specific). 4. Align data among disparate groups. 5. Develop data-driven management algorithms.	Same as above	2014-onward
Lack of an evidence base in traditional participation guidelines	*Establish sports participation registries in those with disease*. 1. Use data to raise level of evidence for Bethesda guidelines. 2. Use practice-based registries to tell us "how we are doing." 3. Align data among disparate groups. 4. Develop data-driven management algorithms	Same as above	2014-onward
Gaps in ECG screening debate	*Raise quality of ECG algorithms and validate prospectively* 1. Convene multidisciplinary group of experts to define how interpretation algorithms should be derived and developed. 2. Encourage the derivation of algorithms on the basis of knowledge of underlying structure (echo or MRI). 3. Validate algorithms prospectively in clinical trials.	Same as above	2014-2017
	Efficacy 1. Encourage randomized controlled trials with well-defined outcomes. 2. Determine if identification of an underlying high-risk condition qualifies as a surrogate outcome (see Table 1—Metrics).	Same as above	2014-onward

CT indicates computed tomography; ECG, electrocardiogram; and MRI, magnetic resonance imaging.

interpret cardiac testing and treatments, and assist in immediate and long-term RTP decisions that have the potential to ensure optimum safety for the athlete. Although their role in many cardiovascular facilities has been limited to performance of stress testing, exercise physiologists' knowledge base is invaluable for the cardiovascular care of athletes.

Some of these providers may be directly responsible for athlete cardiovascular care on the front lines, although it is more likely that they will provide care off the playing or practice field. In addition, they are responsible for defining the content of undergraduate, graduate, and continuing medical education, and developing standards of care. Non-physician staff members are also critical to developing and implementing standards. These providers belong to or work closely with the AAFP, AAP, ACC, American College of Sports Medicine (ACSM), American Heart Association (AHA), AMSSM, AOASM, American Society of Echocardiography, Association of Black Cardiologists, Children's Cardiomyopathy Foundation, Heart Rhythm Society, Society for Cardiovascular Magnetic Resonance, and Hypertrophic Cardiomyopathy Association.

Research scientists and funding agencies: Epidemiologists, exercise scientists, and academic clinicians working in both the basic and clinical sciences perform much-needed research about the risks and benefits of exercise, the adaptation of the cardiovascular system to training, and the interaction of the heart and vasculature with the internal and external athletic environments. They are supported by funding agencies and health policy makers, and belong to or work closely with the Centers for Disease

TABLE 11 Potential Research Directions: Sports and Exercise Cardiology

1. Epidemiology of cardiac events in athletes
   a. Detect the true prevalence and clinical relevance of heart diseases in athletes.
   b. Identify individuals at highest risk.
   c. Develop standardized outcomes metrics for fatal and non-fatal events.
   d. Determine the true rates of SCD and SCA in well-defined athletic populations.
2. Evaluation
   a. Determine the predictive value of symptoms.
   b. Define normative data and reference values for ECG, echocardiography, and cardiac MRI in multi-racial and multi-ethnic American athletes at different levels (high school through Masters).
   c. Characterize chamber remodeling in all ages and levels of athletes.
   d. Correlate symptoms with underlying structure.
   e. Correlate surface ECG with underlying structure.
   f. Elucidate why some athletes remodel and others do not, even among homogeneous athletic populations.
   g. Prospectively validate cardiac testing in athletes.
   h. Define which cardiac tests (e.g., ambulatory monitoring, stress protocols) produce the greatest and most cost-effective diagnostic yield.
   i. Conduct randomized trials of PPE alone versus PPE plus ECG in varying demographic groups.
3. Management
   a. Determine the efficacy of defibrillation (AEDs and ICDs).
   b. Create a data-driven approach to differentiating pathology from athletic adaptation with regard to:
      i. Cardiomyopathies;
      ii. Aortic dimension, pulmonary pressure, and valvular regurgitation; and
      iii. Long QT, Brugada, and early repolarization.
   c. Specify the best treatments for asymptomatic WPW and atrial fibrillation.
   d. Identify the best way to diagnose and treat anomalous coronary artery and determine which variants require treatment.
   e. Correlate changes seen in endurance athletes with long-term outcomes.
   f. Determine risk and/or safe levels of exercise in individuals with heart disease to allow for revision of participation guidelines.

AED indicates automated external defibrillator; ECG, electrocardiogram; ICD, implantable cardioverter defibrillator; MRI, magnetic resonance imaging; PPE, pre-participation evaluation; SCA, sudden cardiac arrest; SCD, sudden cardiac death; and WPW, Wolff-Parkinson-White. (From Lawless, 14)

Control and Prevention; National Heart, Lung and Blood Institute; AHA; and other funding organizations.

Sports governing bodies: National sports governing bodies, including professional leagues (e.g., Major League Baseball, Major League Soccer, the National Basketball Association, the National Football League, the National Hockey League), the U.S. Olympic Committee, National Collegiate Athletic Association, National Federation of High Schools (NFHS), and state sports commissions, are responsible for creating policies regarding care that promote athlete safety, ensuring compliance, and responding to proposed changes in athlete screening protocols that would aim to minimize risk and optimize safety. Other groups, such as the ACC, AAP, AAFP, ACSM, AHA, AMSSM, and National Athletic Trainers Association, can promote safety and standardization through education and accreditation of providers in athlete cardiovascular care and establishment of standards of care.

Payers: The payer environment for athletes differs significantly from that for general cardiac patients. For the professional athlete, player health and workman's compensation insurance policies are negotiated between player unions and the sports franchises or leagues. In general, cardiac screening (if required by overall league cardiac policy or cardiovascular committee) is not covered by insurance and is instead paid for directly by the teams or league. If athletes require further evaluations, testing is generally covered by insurance or team budgets (personal communications, Dr. Andy Tucker, National Football League Cardiovascular Committee, September 27, 2013). At the Division 1 collegiate level, athlete PPE and any cardiac screening are paid for by the athletic department. Further consultation or cardiac testing is reimbursed by athlete insurance policies. Although PPE is required of high school student-athletes prior to sports participation, the $25-$35 (average) cost often is paid for by the parents. If a cardiac condition is suspected, then additional testing is submitted to the student's health insurance plan. Payers can be key collaborators; their interests can drive data gathering and allocation of resources. Payers include athlete health insurance and workman's compensation carriers (for professional athletes), event organizers, individual athletic departments, and professional teams and leagues.

Industry: Industry partners can contribute tremendously to the advancement of sports and exercise cardiology through innovation and by making new technologies available to providers and patient-athletes. Potential innovations include enhancing the ability of existing clinical tools to detect underlying cardiac conditions in athletes, and creating new tools to enhance the ability to monitor athletes under conditions of sports. Both individually and in partnership with researchers and professional organizations, industry is able to assist with standardization of cardiac testing protocols in athletes, development of normative data, creation of interpretation algorithms in American athletes, and support of registries. Industry can also assist in communication with healthcare providers and dissemination of information through education.

TABLE 12 Advocacy and communications

Gap(s)	Strategies and Methods	Responsible Parties	Time Frame
Lack of coordinated advocacy efforts that have support of all stakeholders providing athlete CV care	Create state-wide athlete CV care task forces. 1. Suggested members: AAP, AHA, ACC, AAFP, school nurses association, PAs, state high school activities associations, DHHS, ATCs, state boards of education, key sports medicine providers 2. Suggested areas for policy creation: • Required use of current 4th PPE forms (paper or electronic PPE) • Which providers can perform PPEs? • Providers performing PPEs be educated and/or certified in cardiac assessment in adolescents • Cardiologist performing consultation obtain education and/or certification on cardiac assessment in adolescents • Every public and non-public school in the state has 1 or more AEDs. • All coaches, licensed ATCs, ADs, administrators and school nurses be trained in CPR and AED use; • Each school must develop an Emergency Action Plan (EAP) • Details of the sudden death event must be entered into a common registry • Educate all student-athletes and their parents/guardians on signs/symptoms of SCA/SCD, and certify in writing that they have been educated. • All grade 7-12 school students are recommended to be trained in SCA/SCD, CPR, and AED use	State chapters of AAFP, AANP, AAP, AAPA, ACC, ACP, ACSM*, and AHA; NATA, key state sports medicine physicians, school nurses, state high school activities associations, DHHS, boards of education, athletic directors, coaching staff, athletes, educators, parents, public, and media	2014-2015
Lack of standardization of screening methods	Standardize best practices for screening throughout the USA 1. Guidance provided by national professional societies and professional organizations to define "standards" 2. Standards include: • If we screen, who, how, and why we screen; • RTP recommendations based on positive AHA elements, or test findings; and • Attempts to reduce or eliminate disparities in care. 3. Can be administered at state level (see above task force plan for state initiatives)	Healthcare provider professional and scientific organizations: AAFP, AANP, AAP, AAPA, ACC, ACP, ACSM, AHA, AMSSM, AOASM, AOSSM, and NATA; school nurses, athletic directors, and coaching staff; and sports governing bodies	2016
Inconsistent messaging from American professional groups	Enhanced communication among major stakeholders 1. Convene mini-think tanks with representatives from multidisciplinary groups; meet regularly and report to main Think Tank annually 2. Create interdisciplinary communications methods: case discussion boards, listserves 3. Intermittent position statements from stakeholders providing athlete CV care	Same as above plus: payers, industry, athletes, educators, parents, public, legislators, and media	ongoing

AAFP indicates American Academy of Family Physicians; AAP, American Academy of Pediatrics; AANP, American Association of Nurse Practitioners; AAPA, American Academy of Physician Assistants; ACC, American College of Cardiology; ACP, American College of Physicians; AD, athletic director; AED, automated external defibrillator; AHA, American Heart Association; AMSSM, American Medical Society for Sports Medicine; AOASM, American Osteopathic Academy for Sports Medicine; AOSSM, American Orthopaedic Society for Sports Medicine; ATC, Certified Athletic Trainer; CPR, cardiopulmonary resuscitation; CV, cardiovascular; DHHS, Department of Health and Human Services; NATA, National Athletic Trainers Association; PA, physician assistant; RTP, return to play; SCA, sudden cardiac arrest; and SCD, sudden cardiac death. *ACSM, American College of Sports Medicine and its 12 regional chapters.

Athlete-patients, educators, parents, public, legislators, and media: In the absence of a universal electronic athlete medical record, the athlete or parent may be the only source of information regarding prior symptoms, family history, cardiac evaluations, and procedures. Athletes and parents need to be aware of the importance of providing accurate information on the PPE and to the screening examiner and team medical staff. They need to be aware of how to recognize SCA and its prodromal warning signs. Furthermore, as with all care, athlete-patients and parents should be educated about making informed decisions, which implies a basic level of knowledge as well as provider disclosure of risks related to participation in sports. Methods for improving public awareness and outreach can come from both the private and public sectors. Legislators can be instrumental partners in these efforts. Legislative pathways should be investigated and pursued where cost-effective and sustainable methods are proven, safe, and logical. Mass media is a critical tool to educate the general public on PPE, screenings, and risks versus benefits to cardiac health through participation in (or lack of participation in) athletic endeavors. Partnering between the media, professional organizations, and public advocacy groups is advisable to ensure consistent messaging. Encouragement for those with risk factors or symptoms to receive comprehensive cardiac evaluations should be addressed in a balanced manner in the media.

Critical Areas and Strategies for Action

As issues in younger athletes (≤35 years old) have received more attention and robust debate in recent years than have issues facing older athletes, the Think Tank discussion gravitated toward this younger group's needs; however, the general principles can be adapted to meet the needs of older (>35 years old) athletes. The Think Tank organizers selected 4 critical multidisciplinary domains for which participants were charged with identifying the most urgent gaps: 1) Quantifying risks to American athletes; 2) Education, and optimal use of existing clinical athlete care tools; 3) Research, quality, and science; and 4) Advocacy and communications. Once gaps were determined, specific strategies and methods were designed to close those gaps, responsibilities were assigned to specific stakeholders, and a time frame for implementation was created. The time frame was meant to convey the urgency of the issue as well as relative priorities of different recommendations.

Quantifying Risks to American Athletes (Table 8)

Owing to athletic cardiac adaptations, the demands of exercise, and the risks and benefits of vigorous exercise, athletes are considered a distinct patient group, requiring tailored cardiovascular care and science devoted to their unique needs (14,135,136). Regarding cardiac risks to athletes, Think Tank participants defined the most urgent gaps as the need for sports cardiology metrics, for high-quality epidemiologic research, and for education. True cardiovascular risks to athletes are not known because large, prospective, longitudinal cohort studies have not been conducted in young athletic populations with suspected low prevalence of disease, using well-defined, consensus-derived metrics. Retrospective studies of the incidence of SCA/SCD in athletic populations have delivered variable results (42,44–46,75,76), perhaps owing to differing definitions of SCA/SCD, varying methodologies, incomplete data, and overlap with non-cardiac causes of SCA/SCD. In any longitudinal study, the risks of participation, of cardiac testing and procedures, and of not participating must be considered in the risk equation.

To tackle the question of cardiovascular risks to athletes, Think Tank participants first recommended that a multidisciplinary panel of sports medicine and sports cardiology experts convene to address the need to define sports cardiology metrics. These metrics would include whether to include SCA in the numerator of the SCD rate equation, how to handle AED "saves" in data analysis, and whether the numerator should be expanded from the traditional "during or within an hour of physical activity" to include "regardless of activity level." Cohorts of athletes could then be followed for cardiac events during participation (activity-centered), as opposed to, longitudinally (athlete-centered).

Going forward, investigators and those using the data must be aware of differing metrics in the current literature. This is crucial because comparative effectiveness of screening/testing/therapeutic strategies cannot be achieved without clear definition of the numerators and denominators for outcomes. Experts must determine whether identification of an underlying high-risk condition is a meaningful outcome compared with a traditional hard outcome such as SCA/SCD. These questions are similar to what we have faced with other forms of asymptomatic disease, such as silent ischemia in CAD, or functional class 1 (Class A) heart failure/ cardiomyopathy.

Once the metrics have been defined, prospective athlete outcomes registries must be designed that are sports specific and level specific, and that take into account athlete heterogeneity. If hard end-points occur at low frequency in athletic populations, then softer cardiac end-points such as arrhythmias, cardiac consultations, hospitalizations, and need for cardiac procedures or treatments, as well as perhaps sports medicine end-points such as days off practice or out of competition should be considered as alternative end-points. Risks of cardiac testing and treatments, and the risks of a sedentary lifestyle should also be factored into the risk equation.

Education and Optimal Use of Existing Clinical Athlete Care Tools (Table 9)

Think Tank participants identified urgent gaps in knowledge of athlete cardiovascular care, conditions that place athletes at risk, and risk mitigation strategies such as hands-only CPR, recognition of SCA and its warning signs, and optimal implementation of AEDs in schools and athletic venues. To address these gaps, Think Tank participants recommend immediate steps toward optimal use of existing clinical tools through education and/or certification of providers making participation decisions (at all levels). Federal Department of Transportation certification, recently required by providers signing off on commercial driver Department of Transportation physical examination forms (137), serves as a good model for certification. Non-formal certifications can be issued through professional societies as a simple certificate of proficiency in sports cardiology (for cardiologists), and/or performance of PPEs (for primary care providers). Recommended education includes knowledge and use of the 4th PPE, 12 AHA elements, 36th Bethesda Conference guidelines, and Masters Athlete's guidelines. Enhanced presence of existing clinical guidelines on the websites of all national organizations and state chapters can immediately increase awareness of these clinical tools, and knowledge and use of tools can be monitored through performance improvement activities and continuing medical education.

Beyond the promotion of existing clinical tools, Think Tank participants encourage the development of core competencies in sports and exercise cardiology and the inclusion of basic sports cardiology competencies, as appropriate to type of practice, in general certification exams for the following professional groups: cardiologists, sports physicians, primary care providers (pediatricians and family practitioners, athletic trainers, physician assistants, nurse practitioners, school nurses, athletic directors, and coaching staff). The ACC Sports and Exercise Cardiology Section has recently outlined its vision for sports cardiology in the United States (14) and is in the process of developing core competencies for both adult and pediatric cardiologists.

At the local level, athlete cardiovascular care lends itself particularly well to team-based approaches, which provide the athlete with the expertise of all those with a stake in athlete cardiovascular care across the continuum. Gaps at multiple levels in knowledge of risk mitigation strategies—such as hands-only CPR, recognition of SCA and its warning signs, optimal implementation of AEDs in schools and athletic venues—are probably best addressed at the state level (see Advocacy section). But a national coalition of professional organizations can create an educational tool kit that can be used by all 50 states to educate all stakeholders and providers about primary and secondary prevention strategies. Creation and distribution of public service announcements at sporting events can promote hands-only CPR and early application of the AED. Legislation in all 50 states should be considered (see Advocacy section).

Research, Quality, and Science (Table 10)

Think Tank participants recognized that the need for rigorous research and meaningful data represented one of the most pressing and severe gaps in sports and exercise cardiology. Areas of greatest immediate need are the uncertain predictive value of symptoms; the lack of normative data in large populations of American athletes of varying age, gender, race, ethnicity, size, and sport; the lack of an evidence base for the traditional participation guidelines; and major evidence gaps in the ECG screening debate. The AHA screening guidelines are based on the clinical presentation of underlying inherited diseases and the ability of providers to recognize and act upon these diseases (16). Although many data have been derived from general populations, very little has been generated in athletic populations (14) and nothing prospectively. Therefore, we propose that the sports cardiology community promote and conduct research that examines the predictive value of symptoms in athletes, aligns data among disparate groups, and develops data-driven management algorithms. Importantly, the predictive value of symptoms in athletes presenting to front-line providers may be vastly different from that of symptoms in athletes presenting to cardiologists.

Most of the athlete ECG data have been generated in Europe, with very little generated in the United States. Inherited diseases vary in incidence according to age, gender, and race and ethnicity; thus, it may not be appropriate to extrapolate data from Europe to the United States. Moreover, sports such as American football do not exist in Europe, so it is unlikely that European ECG and echocardiographic data would be applicable to this group. Normative data in American football need to be reviewed and norms defined for practical application. The same is true for cardiac magnetic resonance imaging, computed tomography, ambulatory monitoring, and cardiopulmonary stress testing. Knowledge gaps can potentially be closed through research evaluation of large numbers of American athletes (level and sports specific).

Once the value of symptoms and normative data for cardiac testing has been described, data-driven management algorithms can be designed. Although management algorithms have been developed for relatively healthy athletes, those with congenital, genetic or acquired cardiac disease who wish to participate in athletics (competitive or recreational) have special needs that have not been well addressed in the past. Although there have been guidelines (15) addressing participation eligibility, a great number of adult patients choose, with informed consent, to participate in activities that some professionals feel are too dangerous. The concept of informed consent and overall quality of life issues for the athlete should be taken into account when drafting such future guidelines; however, fully informed consent implies there are some risk data to present to the athlete with disease who hopes to participate. To fully inform the athlete, much like when patients are counselled regarding the risk of aortic valve surgery or heart transplant, an estimate of risk must be presented. This cannot be done without research-based registries that include those with disease. The implantable cardioverter defibrillator registry is a start, but similar studies must be considered in all those with disease who wish to participate. Other sports cardiology research priorities have been outlined in a recent paper from the ACC Sports and Exercise Cardiology Section (**Table 11**) (14).

Advocacy and Communications (Table 12)

Think Tank participants determined that the most crucial gaps in the United States included a lack of coordinated advocacy efforts that have the support of all stakeholders and that controversies regarding screening prevent screening standardization throughout the United States, resulting in inconsistent messaging from American professional groups. To close these gaps, Think Tank participants propose the creation of a coalition of national American professional groups working in collaboration, who would meet every 2 years to create uniform standards and present a consistent, unified message to providers. Recognizing that such policies are best implemented on a state-by-state basis, the Think Tank also recommends the creation of state-wide athlete cardiovascular care task forces.

Methods to improve student-athlete cardiovascular care can originate in both the public and private sectors, and from the grass roots to the federal level. Opportunities exist down to the local level in terms of ordinances and policies of municipal recreation departments, although these measures are laborious and tend to be highly variable in appearance. State level efforts seem to be most realistic and attainable, as these models allow for efficient communication with all stakeholders and fit logically into existing healthcare delivery systems. We suggest that multidisciplinary state-wide task forces be formed in all 50 states, consisting of representatives from: state chapters of the National Athletic Trainers Association, AAP, AAFP, ACC, ACSM, AHA, school nurses association, physician assistants, state high school activities/athletics associations, Department of Health and Human Services, state boards of education, and medical examiners. The goals of each task force will vary from state to state, but advocacy efforts can be focused on the following: setting standards as to who can perform the PPE; requiring the 4th PPE in all states; and requiring that providers performing PPEs or cardiac consultation be educated and/or certified in cardiac assessment of adolescents; that every public and non-public school in the state has 1 or more AEDs; that all coaches, licensed athletic trainers, athletic directors, administrators, and school nurses be trained in CPR and AED use; that each school develop an Emergency Action Plan (EAP); that details of any SCA/SCD event be entered into a common registry; that all student-athletes and their parents/guardians be educated regarding the signs/symptoms of SCA/SCD; and that all grade 7-12 school students have the opportunity to be trained in SCA/SCD, CPR, and AEDs. There is some evidence that state-based advocacy efforts have been fruitful (21,24,126–128).

It is important to appreciate that each state must evaluate the needs of its community and work closely with professional organizations (participants in producing this document), to determine the appropriateness of legislative initiatives on a state-by-state basis. Examples of successful use of legislative initiatives include at least 1 piece of AED legislation in all 50 states (138) as well as expansion of Good Samaritan legislation in other states. On the federal level, the reality of legislative initiatives does not seem as easy to achieve. The rural AED act has received some funding in the past, but it remains a battle to maintain funding levels. Although there are currently bills in the House and Senate that will provide both education on creating EAPs for schools in the event of a cardiac emergency and SCA risk assessment tools to school age children (HEARTS Act [139]), these initiatives are slow-moving and have lacked public awareness and support to aid their passage. In the private sector, various nonprofit entities are seeking to improve cardiac assessments and prompt access to defibrillation. These private initiatives raise awareness and, although well meaning, may not fully address the needs of a particular community owing to limited resources. Collaboration and partnership between state and federal interests, professional organizations, nonprofit organizations, and patient advocacy organizations (all on state-by-state basis, outlined above) offer the best chance for meaningful change in policy practice and, ultimately, outcome improvement in these areas.

Think Tank participants felt we could do a better job at standardizing screening methods throughout the United States. National professional societies and professional organizations can improve efforts to define “standards” and their implementation by addressing issues including: if we screen, who we screen, how and why we screen; RTP recommendations based on positive AHA elements or test findings; and attempts to reduce or eliminate disparities in care. Consideration should be given to collating all major athlete participation guidelines (4th PPE, 36th Bethesda Conference, 12 AHA elements) into 1 guideline. This approach has merit because a student athlete may be cleared by a primary care provider, with or without cardiology consultation. This will require coordination between all major professional societies with a stake in athlete care. Guidance can be provided by a coalition of national professional societies, but implementation on a state-by-state basis is recommended to achieve optimal distribution and effectiveness. The coalition of national stakeholders, meeting on a regular basis, can solve the problem of inconsistent messaging.

Individual Athlete Advocacy

Resources should be allocated to provide education efforts that ensure athletes know signs and symptoms as well as how and to whom to report these concerns in a manner they feel is safe and protects their confidentiality. In the context of community-based screening initiatives, effectiveness must be weighed against the risk of false reassurance and communicated to participants. Whether screenings include history and physical alone or add ECGs or echocardiograms, the value added and the countervailing false positive/false negative rates should be reported to participants in clearly comprehensible language.

The minor athlete requires special consideration. Choices made on behalf of a minor athlete by parents or guardians are of special concern. The athlete's choice to participate may be overruled by parents, physicians, or the governing body of the sport. Special attention should be paid to the emotional needs of this population.

Advocacy and awareness efforts using mass media are critical tools for educating the general public regarding what they can and cannot expect from community-based screenings as opposed to full clinical evaluation by a cardiologist. Educational efforts addressing both the risks and the benefits to cardiac health presented by participation in (or lack of participation in) athletic endeavors, both organized and recreational, should be enhanced and communicated to the public. Encouragement for those with risk factors to receive comprehensive cardiac evaluations should be addressed in a balanced manner in the media.

SECTION 5. SUMMARY AND NEXT STEPS

The ACC Sports and Exercise Cardiology Think Tank was convened to define the current cardiovascular issues and needs of the American athlete and to develop an action plan to guide future cardiovascular care efforts. Participants felt strongly that, rather than occurring as an isolated event, our discussion should serve as the beginning of an on-going dialogue and collaboration between highly diverse stakeholders. Logical first steps are listed below.

1. Development of a directory of the multiple participating organizations, with a list of ongoing and planned activities in the domain of athlete cardiovascular safety. Activities could be classified as we have done here: quantifying risk, education, optimal use of existing tools, research, advocacy, and communications. This would allow for a comprehensive approach, less duplication of efforts, greater speed and efficiency, and optimal collaboration.
2. Commitment by the Think Tank participants to meet regularly to discuss athlete cardiovascular care issues and to disseminate Think Tank proceedings to their respective organizations. Mini-think tanks with representatives from key organizations could meet regularly to discuss a particular subject, such as metrics, and report their findings to the Think Tank annually or every other year.

From our action plan, we have suggested the following mini-think tanks or task forces would qualify as priorities (in order of urgency):

a. Creating an athlete cardiovascular care task force in each state
b. Promoting development of team-based care at local levels (athletic trainers, team physicians, school nurses, primary care providers, cardiologist and cardiac subspecialists)
c. Developing evidence-based symptom management
d. Defining normative data in American athletes: ECG, echocardiography, magnetic resonance imaging, computed tomography, ambulatory monitoring, stress testing; closing knowledge gaps through research involving large numbers of American athletes (age level and sports specific)
e. Reviewing current sports cardiology metrics; proposing additional end-points
f. Creating prospective athlete outcomes registries linked to specific metrics
g. Optimizing implementation of existing clinical tools through enhanced education and/or informal certification of multiple and diverse providers; includes knowledge and use of 4th PPE, 12 AHA elements, 36th Bethesda guidelines, masters athletes guidelines
h. Creating competencies for all those involved in athlete cardiovascular care that are appropriate to type of practice, in collaboration with respective professional societies and board examiners such as cardiologists, sports physicians, primary care physicians (pediatrics and family medicine), athletic trainers, physician assistants, advanced practice nurses, school nurses, athletic directors, and coaching staff
i. Educating athletes and all front-line providers about warning signs and symptoms for early identification of SCA-related conditions, and about actual recognition of SCA occurrence
j. Enhancing widespread availability of AEDs, developing EAPs, and promoting hands-only CPR

Only through committed and focused collaboration can these goals be achieved and the practical day-to-day cardiovascular care of athletes be improved. For these efforts to be successful, they must be conducted by multidisciplinary teams of medical and nonmedical scientists, with support from professional societies representing cardiology and its subspecialties primary care and all its disciplines, sports medicine, and athletic training. Our professional societies, funding agencies, payers, and industry must be willing to invest in athlete cardiovascular safety. It is hoped that these Think Tank proceedings will stimulate and support meaningful, continued efforts in the future in this important area.

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APPENDIX 1. LISTING OF AUTHOR RELATIONSHIPS WITH INDUSTRY AND OTHER ENTITIES (COMPREHENSIVE)—PROTECTING THE HEART OF THE AMERICAN ATHLETE: PROCEEDINGS OF THE AMERICAN COLLEGE OF CARDIOLOGY SPORTS AND EXERCISE CARDIOLOGY THINK TANK

Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Christine E. Lawless	Sports Cardiology Consultants, President	None	None	None	None	None	None
Chad Asplund	Eisenhower Army Medical Center-Director, Military Sports Medicine	None	None	None	None	None	None
Irfan M. Asif	University of Tennessee Family and Sports Medicine—Assistant Professor; Fellowship Director, Sports Medicine	None	None	None	None	None	None
Ron Courson	University of Georgia—Senior Associate Athletic Director	None	None	None	None	None	None
Michael S. Emery	Carolina Cardiology Consultants	None	None	None	None	None	None
Anthon R, Fuisz	Medstar Washington Hospital Center-Director, Cardiac MRI	None	None	None	None	None	None
Richard J. Kovacs	Krannert Institute of Cardiology-Professor of Clinical Medicine	• Biomedical Systems • Insight Pharmaceuticals • Theravance† • Xenoport	None	None	• Biotie (DSMB) • Eli Lilly (DSMB)†	• Cook Incorporated Med Institute†	None
Silvana M. Lawrence	Baylor College of Medicine—Associate Professor, Department of Pediatrics, Section of Cardiology	None	None	None	None	None	None
Benjamin D. Levine	Institute for Exercise and Environmental Medicine	None	None	None	None	None	• Defendant, 2013, Postural Orthostatic Tachycardia Syndrome
Mark S. Link	Tufts Medical Center	None	None	None	None	None	None
Matthew W. Martinez	Lehigh Valley Health Network	None	None	None	None	None	None
G. Paul Matherne	University of Virginia Health Sciences Center-Division Chief of Pediatric Cardiology	None	None	None	None	None	None

Continued on the next page

APPENDIX 1. CONTINUED

Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Brian Olshansky	University of Iowa Hospitals-Professor of Medicine	• Arrhythmia Grand Rounds* • BioControl • Boehringer Ingleheim • Boston Scientific (guidant) • Combined Medicare Medicaid Services • Daiichi Sankyo • Gerson Lehman • Medtronic† • Sanofi Aventis	None	None	• Amarin (DSMB) • Boston Scientific (DSMB) • Sanofi Aventis (DSMB)	• Boston Scientific • Executive Health Resources† • Thompson Reuters*	• Defendant, 2013 Event Monitors • Third Party, 2012, Cardiac Arrest
William O. Roberts	University of Minnesota Medical School-Professor, Department of Family Medicine and Community Health	None	None	None	None	None	None
Lisa Salberg	Hypertrophic Cardiomyopathy Association-Chief Executive Officer	None	None	None	None	None	None
Victoria L. Vetter	Children's Hospital of Philadelphia Division of Cardiology-Professor of Pediatrics	None	None	None	None	None	None
Robert A. Vogel	University of Colorado-Professor of Medicine	• Pritikin Longevity Center • National Football League†	None	None	• Sanofi†	None	None
Jim Whitehead	American College of Sports Medicine-Executive Vice President/Chief Executive Officer						

This table represents all relationships of committee members with industry and other entities that were reported by authors, including those not deemed to be relevant to this document, at the time this document was under development. The table does not necessarily reflect relationships with industry at the time of publication. A person is deemed to have a significant interest in a business if the interest represents ownership of ≥5% of the voting stock or share of the business entity, or ownership of ≥$10,000 of the fair market value of the business entity; or if funds received by the person from the business entity exceed 5% of the person's gross income for the previous year. Relationships that exist with no financial benefit are also included for the purpose of transparency. Relationships in this table are modest unless otherwise noted. Please refer to http://www.cardiosource.org/Science-And-Quality/Practice-Guidelines-and-Quality-Standards/Relationships-With-Industry-Policy.aspx for definitions of disclosure categories or additional information about the ACC/AHA Disclosure Policy for Writing Committees.
*No financial benefit.
†Indicates significant relationship.

APPENDIX 2. ABBREVIATIONS

AAFP = American Academy of Family Physicians
AAP = American Academy of Pediatrics
ACC = American College of Cardiology
ACSM = American College of Sports Medicine
AHA = American Heart Association
AED = automated external defibrillator
CAD = coronary artery disease
CP = chest pain
CPR = cardiopulmonary resuscitation
EAC = exercise-associated collapse
EAP = emergency action plan
ECG = electrocardiogram
EMS = emergency medical services
FH_X = family history
PPE = Pre-participation evaluation
PVC = Premature ventricular contractions
RTP = return to play
SCA = sudden cardiac arrest
SCD = sudden cardiac death