Preparticipation Physical Evaluation and Sudden Death in Athletes

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Goals of PPE

- Maximize safe participation.
- Identify medical problems with risks of life-threatening complications during participation.
- Identify conditions that require a treatment plan before or during participation.
- Identify and treat conditions that interfere with performance.
- Remove unnecessary restrictions.

Goals Met?

- Is the pre-participation examination (PPE) an effective screening tool?
Effective Screening
- Identify disease in the population
- Sensitive and accurate
- Practical and affordable

The Evidence
- No data supporting efficacy
- Not effective (Carek and Mainous BMJ USA 2002;2:661)
- Not evidence based
- Routine adolescent exams not useful or cost effective (Montalto 1998, Am Fam Physician)

Expert Opinion
The PPE
- PPEs recommended by expert panel
- Widely performed
- Required by most states
- Required by NFHS and NCAA
- Not a substitute for CPE!

Method
- Qualification of examiners
- Timing
- Frequency (yearly)

Method
- New recommendations
  - every 2 years in young athletes
  - 2-3 in older athletes
  - entry into new school
  - interval evaluation annually
Setting

- Physician’s office
  - ideal
- Coordinated medical team
  - multiple physicians
  - other health care professionals
  - best if single physician reviews history and performs exam

Content

- History
- Physical examination
- Routine screening tests not indicated
- Determine disposition

History

- Most important aspect of PPE
- Potential to identify 75% of the problems affecting athletes
History

- Medical history
  - denied participation
  - ongoing medical condition
- Medications and supplements
- Allergies and anaphylaxis

Cardiovascular problems (more to come!)
- dizzy, light-headed or passed out during or after exercise
- chest pain, discomfort or pressure during exercise
- racing heart or skipped beats
- high blood pressure, high cholesterol, a heart murmur or history of a heart infection

Surgical history
- have you ever had surgery
- have you ever had spent the night in the hospital

Musculoskeletal history
- injury causing missed practice or game time
- broken bones, dislocated joints
History

- Musculoskeletal injury
  - stress fracture
  - injury requiring: x-rays, MRI, CT, surgery, injections, PT, brace, cast or crutches
  - atlantoaxial instability
  - regular brace use

History

- Asthma
  - asthma or allergies
  - cough, wheeze, difficulty breathing with exercise
  - family history of asthma
  - past or present inhaler/asthma medication

History

- Paired organs
- Viral illness
- Dermatologic conditions
  - rashes or skin problems
  - herpes
History

- Neurologic conditions
  - head injury, concussion, confusion, memory loss
  - seizures
  - headaches with exercise
  - numbness, tingling, weakness
  - unable to move arm or legs

History

- Heat illness
- Sickle cell trait or disease
- Eyes and vision
  - vision or eye problems
  - glasses or contact lenses
  - protective eye wear

History

- Nutritional concerns
  - happy with your weight
  - trying to gain or loose weight
  - has anyone recommended you change or loose weight
  - limit or control what you eat
History

- General concerns
- Menstrual history
  - started menstruation
  - age at first menses
  - how many periods in the past 12 months
- Immunization history?

Physical Examination

- Screening tool
  - cardiovascular
  - musculoskeletal
  - neurologic
- Guided by history

Physical Examination

- Height
- Weight
- BP
- Respiration
BMI for Age 2-20

- Underweight
  - <5th percentile
- At risk for overweight
  - 85th-95th percentile
- Overweight
  - ≥95th percentile

Physical Examination

- Eyes (visual acuity, pupils)
- Oral cavity
- Ears
- Nose
- Lungs

Physical Examination

- Cardiovascular system
  - blood pressure
  - pulses (radial, femoral)
  - heart (rate, rhythm, murmurs)
Hypertension in Children

- Normal
  - < 90th percentile for age, sex, and height
- High Normal
  - 90-95th percentile for age, sex, and height
- Hypertension
  - 95-99th percentile for age, sex, and height
- Severe Hypertension
  - > 99th percentile for age, sex, and height

Physical Examination

Abdomen
- masses
- tenderness
- organomegaly

Physical Examination

Genitalia (males only)
- testicles
- hernia

Skin
- rashes
- lesions
Physical Examination

- Musculoskeletal system
  - contour
  - range of motion
  - stability
  - symmetry

Joint Specific Exams

- More definitive than screen
- Time consuming
- Low yield in asymptomatic athlete
- Use as indicated by history and screening exam

Neurologic System

- Normal musculoskeletal exam implies normal motor neurologic function
- Additional testing if indicated on history or exam
Clearance

- Determine initial disposition
- 3.1% - 13.9% require further evaluation

Clearance Categories

- Cleared without restrictions
- Cleared with recommendations
- Not cleared pending further evaluation/treatment
- Not cleared for certain/all sports

Considerations

- Does the problem place the athlete at increased risk for injury or illness?
- Is another participant at risk?
- Can the athlete participate with treatment?
- Can limited participation be allowed?
- If clearance denied, what activities are allowed?
# Medical Conditions and Participation

[Image of Medical Conditions and Participation]

http://aappolicy.aappublications.org/content/full/pediatrics;107/5/1205

## Classification of Sport

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# Sudden Death in Athletes

Remember, a major goal of the PPE is to identify medical problems with risks of life-threatening complications during participation.
Historical Perspective

First report of an unexpected death of the Greek soldier Pheidippides on completing a historic run from Marathon to Athens to deliver the message of victory over the Persians in 490 B.C.
- Namesake of the marathon
  - Distance of 42.195 kilometers (26 miles 385 yards) did not become standardized until 1921

Definition

Sudden death: "an abrupt unexpected death of cardiovascular cause, in which the loss of consciousness occurs within 1 to 12 hours of onset of symptoms" (1,2, 3).
- Majority occur during or immediately after exercise
  - May occur at rest or during sleep
  - The sedentary are not routinely been included into the definition of "athlete."

Epidemiology

- True incidence difficult to determine.
- Previously suggested incidence as low as 20 per year (1,4).
- Incidence of deaths is in the range of two in 100,000 high school-age athletes per year (40, 41).
  - Most frequent in football and basketball.
Epideimiology

1 in 15,000 joggers to 1 in 50,000 marathoners,
- 1 death per 50,000 to 75,000 man-hours of exercise ...
- Approximately 10 million joggers in the US.

Cardiac Causes of Death in Athletes

- Hypertrophic Cardiomyopathy
- Idiopathic left ventricular hypertrophy
- Congenital coronary artery anatomic anomalies
- Tunnled left anterior descending coronary artery
- Commotio Cordis
- Ruptured Aortic Aneurysm
- Ventricular Arrhythmias
- Wolff-Parkinson-White Syndrome
- Commissural coronary artery
- Brugada Syndrome
- Mitral valve prolapse
- Idiopathic left ventricular hypertrophy
- Atherosclerotic coronary artery disease
- Dysplasia
- Dilated cardiomyopathy

Other Causes of Sudden Death in Athletes (1,6,7)

- Exercise-induced asthma and respiratory arrest
- Exercise-induced anaphylaxis
- Sarcoidosis
- Malignant hyperthermia
- Heat stroke
- Sickle cell trait
- Gastrointestinal bleeding
- Rhabdomyolysis
- Head trauma
- Spine trauma (in pole vaulting)
- Non-penetrating neck blow with rupture of cerebral artery (ice hockey)
Drug-Related Athlete Deaths

- Ephedrine (Ma-Huang or herba ephedra)
- Cocaine
- Amphetamines
- Anabolic steroids (oxymetholone, methandrostanolone, stanozol, etc)
- Erythropoietin
- ETOH
- Ergotamine derivatives
- "Energy" drinks
- Others

Athlete's Heart

- Exercise: significant increase in heart rate, contractility of the heart and increase cardiac output and oxygen consumption.
- Benefits: improvements in lipid profile, weight loss, reduction of insulin resistance and the risk of type 2 diabetes, risk of myocardial infarction, heart failure, and death caused by cardiovascular disease.
- Children and adolescents should do 1 hour or more of physical activity every day.
**Athlete’s Heart**

- Systemic training will increase cardiac mass and dimensions, and trigger structural remodeling in many athletes (1,14,17-20).
  - Physiologic adaptation to systematic athletic training, and termed "athlete’s heart."
  - Left and right ventricles and left atrium become enlarged but function of the heart remains preserved.

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**Athlete’s Heart**

- Systolic function is normal in highly trained athletes and the majority of HCM patients.

  - Important differences in diastolic filling patterns:
    - Physiologic hypertrophy: consistent with a normal diastolic function with even increased early diastolic filling.
    - HCM: diastolic dysfunction (mostly relaxation disturbances) occurs in the majority of patients (1,31).
Athlete’s Heart

- Distinguishing physiological hypertrophy from hypertrophic cardiomyopathy in athletes remains difficult
- Study of 17 patients in France
  - In active athletes presenting with ambiguous left ventricular hypertrophy, abnormal serum NT-proBNP levels indicate hypertrophic cardiomyopathy, whereas normal values are inconclusive (1,33)

- 15 percent of trained athletes demonstrate left ventricular cavity enlargement. (1)
- 20 percent of retired, deconditioned athletes in a longitudinal echocardiographic study, showed incomplete reversal with substantial residual chamber dilatation (1,21)
  - Can’t exclude with certainty that ventricular remodeling due to intense conditioning may have adverse consequences long-term (1,19,22)

Sudden Death

- Most cases of sudden death are attributed to ventricular arrhythmias in the setting of structural heart disease.
- Ventricular ectopy in elite athletes is not directly related to the magnitude of physiologic LV hypertrophy (1,34)
Sudden Death

Sports are not the cause of mortality, but can trigger sudden death in those athletes who are affected by cardiovascular conditions predisposing to life-threatening ventricular arrhythmias during exercise (1,28).

Hypertrophic Cardiomyopathy

Consistently been the single most common cardiovascular cause of sudden death in the US (1,32).

- Familial autosomal dominant disorder with variable expression.
  - Relatively common in the general population (1:500 people) (1,10).
  - The most common genetic disorder of the cardiovascular system with a prevalence of 0.2% (1,31).

Hypertrophic Cardiomyopathy

- Thickening of the ventricular septum and/or other segments of the left ventricle with or without a partial obstruction to the blood flow out of the left side of the heart.
- HCM is usually diagnosed by an imaging test (echocardiography or magnetic resonance imaging [MRI]).
  - Electrocardiogram (ECG) is often abnormal in patients with HCM.
Hypertrophic Cardiomyopathy

- Increased physiologic demands on the heart produce alterations in electrolytes, blood volume and levels of hydration
  - Increase sympathetic tone, decreases parasympathetic tone
  - Multiple interactions act as triggers for potentially lethal ventricular arrhythmias (1,11)

Hypertrophic Cardiomyopathy

- Increased myocardial mass and insufficient regional perfusion during high-intensity exercise cause myocardial ischemia, and over time, replacement fibrosis, both of which may act as independent triggers of arrhythmias
  - Patients with HCM that survived a “sudden death incident” had a very high incidence of inducible ischemia on thallium stress-testing (1,12)

Hypertrophic Cardiomyopathy

- Lack of appropriate blood pressure and heart rate response to exercise may act as the initial event cascading into a hemodynamic collapse with loss of consciousness
  - Partial obstruction present at rest may increase twice as high with intense physical exercise compared to levels at baseline, which can potentially result in myocardial ischemia, hemodynamic compromise and arrhythmias (1,13)
Congenital Coronary Anomalies

- Second most frequent cause of athletic field deaths.
- Mostly a wrong origin of the left main coronary artery.
- Usually diagnosed by echocardiography, MRI and/or coronary angiogram.

Each variation of normal anatomy may have its specific mechanism of induction of hemodynamic compromise and/or lethal arrhythmias.

Common Mechanism: the expansion of the aorta or pulmonary arteries from the increased stroke volume changes the take-off angle of the artery and, as a consequence, the artery may become compressed (1,3,14,15).

The compression of the arterial lumen may only be present at vigorous exercise.

“bridging” has largely similar mechanics, except the exact location is more distal in the vessel but not at the origin.

Prolonged myocardial ischemia, especially if it occurs repeatedly, is believed to be sufficient enough to trigger ventricular fibrillation (1,3,14,15).
Commotio Cordis
- Blunt, nonpenetrating, innocent-appearing blows to the chest
  - Blows must be directly over the heart.
  - Must occur within 15-30 msec before the T-wave peak (which represents 1% of the cardiac cycle).
  - Can induce ventricular fibrillation, complete heart block and ST elevation (1,24-26)

Not uniformly fatal, approximately 15% of the victims are known to have survived, usually with prompt cardiopulmonary resuscitation and defibrillation. (1,38)

Arrythmias
- Abnormalities of the conduction system may result in cardiac arrest, collapse, loss of consciousness and death:
  - Congenital Long QT Syndrome
    - Ventricular tachycardia which can be related to exertion or stress, occurs in 80% of untreated patients
      - Can occur with or w/out exercise, emotional stress (1,23)
**Arrhythmias**

- **Wolff-Parkinson-White**
  - Most frequent complication is rapid atrial fibrillation with a rapid ventricular response, which may lead to cardiac arrest
  - With or without exercise
- **Brugada Syndrome**
  - "Idiopathic Ventricular Fibrillation"
  - Sodium channel abnormality
  - Incomplete RBBB and ST segment elevations in precordial leads

**Arrhythmogenic Right Ventricular Cardiomyopathy**

- Fatty infiltration and fibrosis of the right ventricle which predisposes the athlete to exercise-induced ventricular tachyarrhythmias
- The leading cause of sudden cardiac death in young athletes in Europe. (1,32)

**Myocarditis**

- Inflammatory infiltration of the myocardium
  - Sometimes with systemic inflammation
  - Most commonly viral, Coxsackievirus B in more than 50% of cases
  - Illicit drug use is sometimes associated with myocarditis
  - Death may occur in the presence of either active or healed myocarditis
Screening

Current U.S. recommendations don’t include ECGs, most notably due to a lack of policy mandate and infrastructure to support this (29).

- Five million competitive athletes at the high school level (grades 9–12).
- More than 500,000 collegiate (including NCAA, NAIA, junior colleges).
- 5,000 professional athletes.

Screening

- Does not include youth, middle school, and masters level (age 30 +) competitors for whom reliable numbers are not available.
- Relevant athlete population available for mass screening may be as large as 10 million people per year.
- Total estimated cost of mass screening for that many athletes, along with the follow-up required for abnormal findings, is more than $2 billion a year (1,29).

What Do We Do?

- American Heart Association scientific statement:
  - 12-step screening may help reduce sudden death in young athletes.
Personal History

1. Chest pain/discomfort upon exertion
2. Unexplained fainting or near-fainting
3. Excessive and unexplained fatigue associated with exercise
4. Heart murmur
5. High blood pressure

Family History

6. One or more relatives who died of heart disease (sudden/unexpected or otherwise) before age 50
7. Close relative under age 50 with disability from heart disease
8. Specific knowledge of certain cardiac conditions in family members: hypertrophic or dilated cardiomyopathy in which the heart cavity or wall becomes enlarged, long QT syndrome which affects the heart’s electrical rhythm, Marfan syndrome in which the walls of the heart’s major arteries are weakened, or clinically important arrhythmias or heart rhythms.

Physical Examination

9. Heart murmur
10. Femoral pulses to exclude narrowing of the aorta
11. Physical appearance of Marfan syndrome
12. Brachial artery blood pressure (taken in a sitting position)
American Heart Association Scientific Statement

- Parents should verify this information, said members of the expert panel who wrote the statement.
- If any of the 12 screening elements has a “yes” answer, the participant would be referred for further cardiovascular examination.

Further Evaluation

- 12-Lead ECG
- Echocardiogram
- Computerized Tomography
- Holter / Event / Continuous Loop Monitoring
- Magnetic Resonance Imaging
- Exercise Stress Test
- Electrophysiological Testing
- Cardiac Catheterization

Now What?

- 36th Bethesda Conference Eligibility Recommendations for Competitive Athletes With Cardiovascular Abnormalities, Journal of the American College of Cardiology Vol. 45, No. 8, 2005
Hypertrophic Cardiomyopathy

Recommendations:

1. Athletes with a probable or unequivocal clinical diagnosis of HCM should be excluded from most competitive sports, with the possible exception of those of low intensity (class IA). This recommendation is independent of age, gender, and phenotypic appearance, and does not differ for those athletes with or without symptoms, LV outflow obstruction, or prior treatment with drugs or major interventions with surgery, alcohol septal ablation, pacemaker, or implantable defibrillator.

2. Although the clinical significance and natural history of genotype positive-phenotype negative individuals remains unresolved, no compelling data are available at present with which to preclude these patients from competitive sports, particularly in the absence of cardiac symptoms or a family history of sudden death. (30)
**Congenital Coronary Artery Anomalies (w/out hx of MI)**

**Recommendations:**

- 1. Detection of coronary anomalies of wrong sinus origin in which a coronary artery passes between great arteries should result in exclusion from all participation in competitive sports.
- 2. Participation in all sports three months after successful operation would be permitted for an athlete without ischemia, ventricular or tachyarrhythmia, or dysfunction during maximal exercise testing. (30)

**Commotio Cordis**

**Recommendations:**

- 1. Age-appropriate safety baseballs are recommended for use in children up to 13 years of age.
- 2. Although chest wall protectors may prevent traumatic injury in goalies and baseball catchers, insufficient evidence is available to recommend universal use of commercially available chest barriers for all participants in sports, specifically to prevent commotio cordis events.
- 3. AEDs should be available within 5 min after participant collapse at sporting events.
- 4. Survivors of a commotio cordis with ventricular fibrillation (or a presumed aborted event without documented ventricular fibrillation) should undergo a thorough cardiac evaluation, including at least 12-lead ECG, ambulatory Holter monitoring, and echocardiogram. Standard electrophysiologic testing and an implantable cardioverter-defibrillator are not usually recommended.
Commotio Cordis

Recommendations:

- 5. Because data are lacking with regard to the susceptibility for recurrent events, eligibility for returning to competitive sports in survivors is at present a decision left to individual clinical judgment. (30)

Arrhythmias

Recommendations are arrhythmia-dependent.

- Sinus tachycardia and sinus bradycardia appropriate for the clinical situation are not considered abnormal.
  - Sinus arrhythmia and wandering pacemaker are generally considered normal, and no tests are necessary unless the arrhythmias are accompanied by symptoms.
  - Sinus arrhythmia and sinus bradycardia are particularly common in the trained athlete.
- The search for significant structural heart disease is an important element in evaluating athletes with arrhythmias prior to sports participation. (30)

Arrhythmogenic Right Ventricular Cardiomyopathy

Recommendation:

- 1. Athletes with probable or definite diagnosis of ARVC should be excluded from most competitive sports, with the possible exception of those of low intensity (class IA). (30)
Myocarditis

Recommendations:

1. Athletes with probable or definite evidence of myocarditis should be withdrawn from all competitive sports and undergo a prudent convalescent period of about six months following the onset of clinical manifestations.

2. Athletes may return to training and competition after this period of time if:
   - LV function, wall motion, and cardiac dimensions return to normal (based on echocardiographic and/or radionuclide studies at rest and with exercise)
   - Clinically relevant arrhythmias such as frequent and/or complex repetitive forms of ventricular or supraventricular ectopic activity are absent on ambulatory Holter monitoring and graded exercise testing
   - Serum markers of inflammation and heart failure have normalized
   - The 12-lead ECG has normalized. Persistence of relatively minor ECG alterations such as some ST-T changes are not, per se, the basis for restriction from competition. (30)

AEDs on the Field

Recommendations:

1. The AEDs should be available at educational facilities that have competitive athletic programs (including intramural sports and conditioning classes), stadiums, arenas, and training sites, with trained responders identified among the permanent staff. Devices should be deployed so as to provide a response time of less than 5 min.
AEDs on the Field

**Recommendations:**

2. The initial response to a suspected or identified cardiac arrest should be to contact emergency medical services (e.g., 9-1-1), followed immediately by, or concomitant with, initiating CPR and deploying the AED. (30)

ACSM and AHA now recommend that AEDs be placed in high-membership health/fitness facilities, and strongly encourage AED training, presence of trained staff and placement of AEDs in facilities offering special programs to clinical populations. Exercise-related deaths occur more commonly in those who exercise less than once a week. (39)

The incidence of cardiac arrest in young athletes is extremely low (approximately 1% of that reported in middle-age and older adult populations)

- Risk increases with age
- The value of prompt and successful resuscitation and long-term survival is enhanced by the potential of extended life over many decades (30)
AEDs on the Field

Response times from witnessed onset to initial defibrillation of less than 2 to 3 min can provide survival outcomes hovering about 50% (36).

- Rates fall sharply with each passing minute thereafter. By 4 to 5 min, survival is 25% or less, and less than 10% after 10 min (37).

Parting Thoughts

Unrealistic to assume that any single approach—epidemiological surveillance, primary prevention of disease states, clinical interventions of established diseases, or community-based response systems—will have a major impact alone.

Parting Thoughts

Each strategy has a role, in part because a large majority of events occur unexpectedly in the out-of-hospital environment and are not predictable with great accuracy by risk profiling in most clinical circumstances. (35)