Preparticipation Evaluation

An Evidence-Based Review

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Objective: To review available evidence establishing the validity of the preparticipation evaluation (PPE) as a method for screening health risk prior to participation in exercise and sport. Specific emphasis was placed on reviewing original research evaluating methods to screen participants for risk of sudden cardiovascular death. Literature on the current state of the PPE as a screening tool for athletic participation was examined.

Data Sources: Electronic databases were searched for articles relating to mass screening for sports participation and sudden cardiac death in athletes published up to January 2004. Databases searched included Medline (OVID Web, 1966–2004), PubMed (1966–2004), Sport Discuss (1975–2004), Current Contents, CISTI Source (1993–2004), Cochrane Database of Systematic Reviews, and EBM Reviews. Additional references from the bibliographies of retrieved articles were also reviewed.

Selection Criteria: All study designs were retrieved, but only those studying athletes and/or student-athletes under age 36 years were reviewed. Of the original research retrieved, the majority of the articles sought to establish incidence or prevalence of cardiovascular causes of sudden death in athletes or the validity of various screening tools. Original research articles seeking to establish the current use of the PPE in all its various forms were also reviewed. All of the articles selected for review consisted of type II, population-based data.

Data Extraction and Synthesis: The initial literature search identified 639 papers. Of these, 310 articles that met the selection criteria were reviewed, and 25 articles were identified as original research directly relating to the PPE. All of these contained type II evidence—population-based clinical studies. The majority of the literature on the PPE consists of type III evidence—case-based opinion papers and position papers from respected authors and sports medicine societies and reports of expert committees. This literature was also reviewed, but only original research relevant to the PPE is reported in this article. The majority of these studies examined cardiovascular diseases and screening procedures.

Results: The 5 studies that assessed the format or effectiveness of the PPE concluded that it was inadequate. The format of the PPE is not standardized and does not consistently address the American Heart Association recommendations for cardiovascular screening history and physical exams. A variety of health care professionals, some without proper training, administer the PPE. The 12 original studies that looked at specific cardiovascular screening techniques were divided on the effectiveness of history, physical examination, electrocardiogram, and echocardiography for detecting cardiovascular risks for sudden death in athletes.

Conclusions: A PPE is required by most sport organizations in America, but research as to its effectiveness is very limited. PPEs have been mandatory in Italy for many years, and we can draw on some the data recorded over this time. Otherwise, very few studies in America or elsewhere have been performed on the PPE process. The research available indicates that the PPE is not implemented adequately or uniformly. An opportunity exists to create a standardized, validated PPE that meets medical standards for quality and provides sensitive, specific screening of potential participants in sport and exercise.

Key Words: PPE, pre-participation evaluation, pre-participation examination, sport, physical examination screening

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Most states, universities, athletic governing bodies, and professional sports organizations in America and elsewhere require athletes to undergo some type of a medical examination before participating in sports. The legal and insurance reasons for the preparticipation evaluation (PPE) are similar to the medical reasons, which are mainly to screen for injuries or medical conditions that may place an athlete at risk for safe participation.[1] However, the quality of the PPE (standardization, sensitivity, specificity, validity) is not of specific concern to the organizations that mandate it; the quality of the PPE lies squarely with the medical providers administering it. This distinction is critical because, in the past, the format and content of many PPEs have been directed by athletic administrators even though physicians carry out the examinations and sign the forms. Many such evaluations have been woefully inadequate from a medical standpoint. As a result, not much is known about best practices for the PPE.

Sudden cardiovascular collapse on the playing field is rare, but dramatic and tragic when it occurs. The overall preva-

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lence of athletic sudden cardiac death (SCD) is estimated at between 1:100,000 and 1:300,000 in high school athletes.[2] In attempts to identify advance risk factors for SCD, The American Heart Association (AHA) recommends routine screening procedures for student athletes.[3] Unfortunately, the very low incidence of symptoms in the underlying disorders make screening extremely difficult and not cost-efficient. Ideally, through a thorough history and physical examination with further cardiac work-up as indicated, the PPE can detect cardiac abnormalities that may put the athlete at risk.

In 1996, the AHA produced recommendations for cardiovascular screening in athletes.[3] This was a response to the consensus of a panel (appointed by the AHA) comprised of cardiovascular specialists, sports medicine physicians, and a legal expert. Guidelines prior to that time had focused on population-based screening for schools. In 1998, another statement was issued by the American College of Sports Medicine (ACSM) and the AHA, making recommendations for cardiovascular screening in all persons before enrollment and participation in sports and fitness activities.[2] Theses recommendations were based on a review of the literature, consensus of the writing group, and previous statements from the AHA and ACSM. The recommendations were then peer reviewed by "selected authorities in the field representing the AHA, ACSM, American College of Cardiology, the International Health Racquet and Sports Clubs Association, and the Young Men's Christian Association."[4] Both the 1998 and the AHA 1996 recommendations involved a more individual approach to preparticipation screening. For young athletes, a history and physical examination (performed by a health care worker trained in detecting cardiovascular diseases) focused to elicit suspicious cardiovascular conditions was recommended. The AHA panel also recommended the development of a national standard for the PPE to address the varied requirements of national sport governing bodies.[3] In 1999, the AHA issued an addendum to these guidelines, advocating the standardization of PPEs across the country, suggesting that they be performed by licensed physicians at a standard consistent with the AHA recommendations for cardiovascular screening procedures.[2] Participation decisions were recommended to be made by qualified physicians and based on current medical specialty eligibility and participation health guidelines.[5] Today, a wide variety of testing methods and PPE formats still exists, and evaluations are performed by a variety of health care professionals, including physicians, athletic trainers, physical therapists, nurses, and chiropractors.[6]

In 1997, The Physician and Sports Medicine issued a consensus statement that served as a summary of the 1996 AHA recommendations and preparticipation guidelines. This publication, endorsed by 5 medical societies, presents a comprehensive approach to medical history taking, physical examination, diagnostic screening tools, and disqualification from participation for the sports medicine physician.[1] While such documents are useful additions to the literature, they are considered to be type III evidence (collective expert opinion) since they have not used a rigorous epidemiologic approach to consensus such as face and content validity. However, these types of guidelines are typically referred to as industry standards in medical-legal cases. The ideal situation would be to have practice standards based on consensus statements that follow a formal development approach such as that advocated by the Centers for Disease Control.[7]

In addition to questions that identify the best ways to screen for injury and disease, identifying the reasons and circumstances in which full participation should be modified or disallowed has received little research attention. Specific conditions carrying the greatest need for detection are cardiovascular abnormalities that may predispose athletes to sudden death and neurologic problems that predispose athletes to catastrophic injury. Despite nationwide requirements for the PPE, no standardized testing protocol exists. School administrators and health care professionals are struggling to find the most appropriate method to evaluate these athletes. We undertook this critical review of the literature in an attempt to make sense of the current literature and determine if any real evidence for all the current guidelines and recommendations exists. We also sought to establish the existing state of the PPE by reviewing any reports detailing current PPE practices and formats.

METHODS

To review the existing evidence for effectiveness of the PPE, an electronic search was performed on the following databases: Medline (OVID Web, 1966–January 2004), PubMed (1966–January 2004), Sport Discuss (1975–January 2004), Current Contents, CISTI Source (1993–January 2004), Cochrane Database of Systematic Reviews, and EBM Reviews. A *preparticipation* keyword search yielded MeSH headings, which were combined and exploded, as listed in Table 1. The bibliographies of the final articles selected were scanned to assure no articles were excluded. Searches were restricted to human subjects and English language. There were no restrictions on the basis of age groups, sex, or study methodology, and the aim with the search was to be overinclusive. The list of references was downloaded into EndNote reference manager software, including MeSH headings and abstracts and duplicate references were removed. The titles and abstracts of all references were then reviewed, and articles not directly relevant to the athletic PPE (i.e., not age 35 or younger) were excluded. The relevant original research articles and reviews relating specifically to the PPE were retrieved for all remaining references. The search strategy and results are outlined in Table 1.

The initial search identified 639 articles after duplicates were removed, and 310 of these were relevant to the PPE in young athletes. These were reviewed, and 25 articles were identified as original research directly relating to the PPE.

TABLE 1. Results of Electronic Data-base Searches

Source	Search Terms	Yield
Medline (via OVID)	*Preparticipation* keyword search yielded following MeSH headings: Physical examination; sports; sports medicine; athletic injuries; mass screening; medical history taking; cardiovascular diseases; death, sudden, cardiac; questionnaires; school health services	
	Searched on:	
	Medical history taking AND sports (both exploded)	89
	Medical history taking AND sports medicine (both exploded)	36
	Medical history taking AND athletic injuries (both exploded)	58
	Medical history taking AND death, sudden, cardiac (both exploded)	15
	Questionnaires AND sports medicine (both exploded)	56
	Questionnaires AND death, sudden, cardiac (both exploded)	1
	Mass screening AND sports (both exploded)	218
	Mass screening AND sports medicine (both exploded)	42
	Mass screening AND athletic injuries (both exploded)	28
	Mass screening AND death, sudden, cardiac (both exploded)	67
		610 Total
		170 Duplicates
		440 Total
Medline (via OVID)	Exp exercise AND exp mass screening (methods, organization and administration, history)	18
PubMed	*Preparticipation* (all fields) AND *sports* (all fields)	168
		68 Duplicates
		100 Total
	Sports and evaluation or examination yielded invalid studies (not preparticipation)	0
	Periodic health check ups (all fields) OR *periodic health checkup* (all fields) OR *periodic health examination* (all fields) OR *periodic health examinations* (all fields) AND *sports* (all fields)	0
CISTI Source	Preparticipation and sports	23 Duplicates
Cochrane Database of Systematic Reviews	Preparticipation	0
	Sport medicine	0
	Sport	32
EBM Reviews—ACP Journal Club	Preparticipation	0
	Sport medicine	4
	Sport	16
Other	Subtotal	610
Other	Identified through scan of reference list of all retrieved articles	29
	Total	639

Table 2 summarizes the strength of evidence of the 22 of the 25 studies. Two of the 25 original PPE articles were descriptions of the process used at particular institutions, and 1 was an intricate cost-effective analysis of the PPE in high school athletes. These were not included in Table 2 as they are not type II evidence or population-based clinical trials. The majority of the literature on the PPE consisted of type III evidence: case-based or opinion papers, position papers from respected authors and sport medicine societies, and reports of expert committees. Although we reviewed all of the retrieved literature, only the original research papers relevant are presented here. The majority of these studies examined cardiovascular diseases and screening procedures. No articles regarding validity of musculoskeletal screening as part of the PPE were found.

TABLE 2. Strength of Evidence*

Reference	Study Design	Population	Main Dependent Measures	Time Frame	Results
Basso et al[15]	Retrospective case review of autopsy cases from SCD registries in USA and Italy	27 cases of SCD in athletes due to anomalous coronary artery origin	Pathological anatomy	(1) 1990–? in USA (2) 1979–? in Veneto region of Italy	15 had no prodromal symptoms, 10 had premonitory symptoms; 45 syncope, 5 chest pain; ECG normal in 9/9; stress ECG normal in 6/6; 2-D echo normal in 2/2
Corrado et al[12]	(1) Cohort (2) Cross-sectional	269 SCD in young people and 33,735 PPEs in athletes	Pathologic findings as causes of sudden death in athletes vs. nonathletes in Padua, Italy	1979–1996	HCM uncommon cause of death in young athletes (0.7% detected at PPE, 3.5% of CV reasons for restriction from sport) and PPE identification may have prevented SCD
Devlin and Ostman-Smith[20]	Cross-sectional	41 patients with HCM, 66 first-degree relatives, 262 controls, 32 athletes	Echo to determine wall thickness: cavity diameter as a screen for HCM in athletes and nonathletes		M-mode echo septum cavity ratio is good screen for HCM, 6% false-positive rate in athletes with physiologic hypertrophy using defined parameters
Fuller et al[18]	Cross-sectional prospective	5615	Compared ECG to Hx, PE (done by cardiologists) as screen for common causes of SCD in athletes	Over 3 years	ECG more effective screening tool than cardiac Hx/PE in PPE and was efficiently performed on large groups of high school athletes
Glover and Maron[26]	Cross-sectional survey of PPE forms used by high school athletic associations	All 50 states (and the District of Columbia) for a total of 51 jurisdictions, grades 9–12	Items contained on PPE forms; examiners designated to perform screening, compared with 1996 AHA consensus panel recommendations for preparticipation cardiovascular screening		8 states have no approved forms, 17 used forms with at least 9 of the 13 AHA recommended questions; 20 states had either no approved forms or inadequate forms; 21 states permitted nurses or physicians to administer the PPE, and 11 states allow practitioners with limited CV training (chiropractors)
Gomez et al[25]	Mail survey	254/500 schools responded	Proportion of US high schools containing all 3 parts of the AHA recommended CV screening history		17.2% of high schools surveyed used PPE forms containing cardiac history questions recommended by AHA
Kinoshita et al[22]	Retrospective, cross-sectional	n = 1929 (1562 males, 367 females), age 15–34 y	Echocardiograms	1989–1987	Higher incidence of aortic root dilation found in tall athletes; echo should be considered as part of PPE in certain sports
Koester and Amundson[30]	Cross-sectional mail questionnaire to athletic directors in 258 Oregon high schools with 60% response rate	154 school administrators and the PPE forms used in those schools	Compliance with AHA recommendations for CV screening	1999–2000	53% contained fewer than 5 of the AHA recommendations for CV screening
Lewis et al[23]	Cross-sectional	265 Howard University student athletes	2-D echo	1987–1988	11% had MVP, 1 had ASD, 11% had maximal LV thickness of ≥13 mm difficult to distinguish from mild nonobstructive HC

TABLE 2. *(continued)* Strength of Evidence*

Reference	Study Design	Population	Main Dependent Measures	Time Frame	Results
Maron et al[8]	Retrospective case review	158 SCD in trained athletes	Clinical information, interviews, postmortem anatomic, microscopic, and toxicologic data	1985–1995	134 causes were CVD; SCD most commonly due to HCM and precipitated by athletic activity; PPE of limited value in finding underlying CV abnormalities; 134/158 SCDs were explained by CV causes, most commonly HCM (36%) and AOCA (13%); of the 115 athletes who had a PPE, only 3% were suspected of having a CV abnormality, and only 1 athlete (0.9%) was correctly diagnosed
Maron et al[9]	Retrospective, cross-sectional	Minnesota State High School League records for grades 10–12; 1,453,280 total sports participants	Causes of SCD in athletes as reported by insurance program in MN high school athletes	1985–1997	3 SCD: 1 AOCA, 1 aortic valve stenosis, 1 myocarditis
Maron et al[19]	Cross-sectional	501 University of Maryland college athletes	Hx, PE, and ECG used to screen athletes	1984–1985	90 abnormalities on 1 or more of screening tests, 75 were declared normal after more investigations, 1 had mild hypertension, and 14 had Echo evidence of MVP; 3 had mild increases in ventricular septal thickness
Niimura and Maki[11]	Cross-sectional	15,156,346 elementary, junior, and senior high school students in Kanagawa Prefecture	Circumstances and mechanisms of SCD in childhood in schools in Japan	1975–1986	Heart failure (unknown etiology) in 62%, CV disease in 19%, CVA in 14%, heat stroke in 5%; 79% died during sports activities; heart disease screening program detected latent CVD
Nistri et al[21]	Cross-sectional, prospective	34,910 army conscripts from northeastern Italy, 2766 selected for testing based on abnormal findings on PPE	HC defined as LV thickness ≥15 mm on 2-D echo	1992–1996	19 (0.7%) had HC (6 had previous diagnosis)—abnormal antecedents were 11 abnormal ECGs, 3 systolic murmurs, 2 abnormal ECG + murmur, 3 family history; false-positive murmurs, 1822
Pelliccia et al[13]	Prospective, cross-sectional	n = 1273, consecutive sample of Italian elite athletes	Echocardiogram of coronary artery ostia to rule out AOCA	1990–1991	In 1273/1273 cases, the ostia were visualized and reported as normal
Pelliccia et al[17]	Cross-sectional	1005 consecutive Italian athletes, average age 26, 75% male	ECG patterns compared with echo	1993–1995	60% had normal ECG, 40% with abnormalities attributed to physiological cardiac remodeling
Pfister et al[6]	Cross-sectional mail questionnaires	Team physician, athletic trainer, or athletic director of NCAA colleges and universities; 879/1110 responses	(1) PPE forms evaluated for form and content and compared to AHA guidelines; (2) administration and scope of PPE	1995–1997	97% required PPE process, annually 51%, team physicians performed the PPE in 85%, 34% allowed athletic trainers to perform the PPE, 26% used forms that contain at least 9 of the recommended 12 AHA screening questions

TABLE 2. *(continued)* Strength of Evidence*

Reference	Study Design	Population	Main Dependent Measures	Time Frame	Results
Sharma et al[37]	Cohort	1000 athletes age 15.7 and 300 matched controls	ECG changes	1995–1998	ECG changes in junior athletes were similar to those in older athletes
Smith and Laskowski	Cross-sectional	Analysis of PPEs and reasons athletes were disqualified	2739 station-based PPEs in high school athletes		1.9% disqualified and 11.9% required further investigation or follow-up; reasons for restriction from sports: 43.4% MSK, 0.37% cardiac; station format of PPE concluded to be efficient and functional for eliciting reasons for activity restriction or further work-up
Waller et al[10]	Retrospective case review	44,481 necropsies in Marion County, Indiana, reviewed for incidence of SCD in athletes	Autopsy report	1985–1990	18 athletic deaths, 88% cardiovascular; in retrospect, an analysis of PPE screening could have detected most cardiac conditions responsible for SCD; authors suggest screening echo would have been-cost effective in detecting underlying CV disease as would cardiac history and ECG
Weidenbener et al[16]	Cross-sectional	2997 student-athletes at 22 Indianapolis area high schools	Single view parasternal long- and short-axis 2-D echo	1992	64 echo abnormalities: 40 MVP, 10 bicuspid aortic valve, 4 aortic root dilation, 2 VSD, 2 ventricular septal aneurysm, 2 dilated coronary sinus, 1 aortic insufficiency, ASD, right ventricle mass, septal hypertrophy; cost per echo was $7.34
Zeppilli et al[14]	Prospective	3650 (mean age, 30 ± 12 y) Italian athletes at varying levels of competitive sports	TTE of coronary artery in asymptomatic athletes	1986–1996	3 of 3504 athletes suspected of AOCA, with diagnosis confirmed by angiography: AOCA rare in asymptomatic athletes, but TTE by skilled clinicians useful for diagnosis

*All articles are type II evidence.

ASD indicates atrial septal defect; CV, cardiovascular; Dx, diagnosis; echo, echocardiography; Hx, history; MSK, musculoskeletal; MVP mitral valve prolapse; PE, physical examination; TTE, transthoractic echocardiography; VSD, ventricular septal defect.

The original articles identified are grouped and discussed as such:

(1) Eight articles on the nature and extent of cardiovascular disorders in the athletic population
(2) Twelve articles on the appropriateness of specific techniques to screen for cardiovascular disease
(3) Five articles analyzing the effectiveness and methodology behind the PPE

Original research on other important subjects such as heat injury, electrolyte disorders, eating disorders, and pulmonary diseases in young athletes is rare in the literature (this electronic database search revealed only 1 relevant article on asthma in high school athletes and 1 on eating disorders, unrelated to the PPE) and is not discussed in this article.

RESULTS

Screening for Cardiovascular Diseases That Predispose Athletes to Sudden Cardiac Death

Tables 3 and 4 lists the original research articles that report the incidence of life-threatening cardiovascular disorders

TABLE 3. Profiles of SCD in Athletes

References	Subjects	Number of SCDs	Characteristics of Athletes Who Died	Causes of SCD
Corrado et al[12]	269 SCDs in people (younger than 35 y) in Venetio, Italy, 1979–1996	49 SCD in athletes	Mean age, 23 years; soccer, basketball, swimming, cycling, other sports	ARV 22%, CAD 18%, AOCA 12%, HCM 2%
Maron et al[8]	Recorded athlete deaths in US 1985–1995	134 SCD per 158 deaths	Median age, 17; 90% male; mostly basketball + football players (68% SCDs)	HCM 36%, AOCA 13%, other coronary anaomalies 5%, ruptured AAA 5%, ARV 2%, premature CAD 2%
Maron et al[9]	Student athletes from 440 Minnesota high schools in 12 years	3 deaths in 1,453,280 sports participants	All male; 2 cross country, 1 basketball; age 16–17 y	AOCA 33%, aortic stenosis 33%, myocarditis 1/3
Nimura and Maki[11]	15,156 school children in Kanagawa prefecture, 1975–1986	80% (78/97) sudden deaths, 79% (62) of these during sports	Activities at time of death: track, 29; swimming, 7; rest extracurricular	AHF 77%, CHD 0.5%, HCM 0.4%, myocarditis 0.4%, Kawasaki 0.2%, long QT 0.1%, atrial flutter 0.1%
Waller et al[10]	44,481 forensic necropsies in Marion county, Indiana, over 6 years	14/18 deaths in athletes, 6 < age 36 y	Mean age, 40 y; 89% male; sports: jogging, basketball, swimming, cheerleading	Age <36 y: myocarditis 1/6, AOCA 2/6, HCM 1/6, CAD 1/6, MVP 1/6; age >36 y: CAD

References	History/Examination Results	Prevalence/Incidence SCD	Impact of PPE
Corrado et al[12]	14/49 positive Hx, 16/49 positive ECG	0.75/100,000 in young people; 1.6/100,000 in athletes	HCM detected in 0.07% athletes in PPE = 3.5% of CV reasons for disqualification
Maron et al[8]	130 athletes had PPE—only 8 (6%) had accurate CV diagnosis; 115 had Hx/PE: 3% positive findings, Dx in 1 (.9%)	Average 1 SCD/year over 1985–1995: underestimate due to selection bias	130 athletes had standard/advanced PPE, 6% diagnosed correctly: 2 denied participation; 47/48 cases HCM not identified by PPE
Maron et al[9]	Negative Hx/PE	1:500,000 participants; 0.46/100,000 annually	None
Niimura and Maki[11]		5.1/100,000	17 SCDs in 10-year follow-up of heart disease screening program
Waller et al[10]	1: Hx ?CHD, 1: Hx murmur + family Hx	0.01% SCD in athletes <36 y	None for athletes age <36 y

AAA indicates abdominal aortic aneurysm; ARV, arrhythmogenic right ventricle; AHF, acute heart failure; CAD, coronary artery disease; CV, cardiovascular; Dx, diagnosis; Hx, history; MVP, mitral valve prolapse; PE, physical examination.

in athletes, the risk with sport participation, and PPE screening methods. These studies are a mixture of retrospective and prospective observational and cross-sectional studies from the United States, Italy, and Japan. The retrospective studies analyze the causes of SCD in young athletes and involve small sample sizes.[8–11] Most of these studies attempt to correlate the cause of death, usually recorded by autopsy or coroners' records, with any documented findings from history and/or physical examinations performed while the athletes were alive. Several prospective studies involve larger populations and document the prevalence of rare congenital conditions, such as anomalous origin of the coronary arteries (AOCA) and hypertrophic cardiomyopathy (HCM), in athletes.[8–11] The strength of evidence in these and other original research articles reviewed in the current article is presented in Table 2.

Italy has a national screening system in place for its elite athletes, which has demonstrated a lowering of SCD rates from HCM.[12] Corrado et al[12] evaluated 20 years of PPE screening by prospectively studying sudden deaths among athletes and nonathletes less than 35 years of age in the Venetio region in Italy from 1979 to 1996. Pathologic findings in the athletes were compared with their clinical histories and electrocardiogram (ECG) findings. Arrhythmogenic right ventricular cardiomyopathy was the most common cause (22.4%), followed by CAD (18.4%) and AOCA (12.2%). HCM accounted for only 2% (1) of the deaths among athletes but 7.3% (16) of deaths among nonathletes. HCM was detected in 22 athletes (0.07%) at preparticipation screening and accounted for 3.5% of the cardiovascular reasons for disqualification from sports. None of these 22 athletes died in the 8.2 ± 5-year follow-up period. Thus, the authors conclude that HCM is an uncommon, though detectable, cause of death in young athletes, and preparticipation screening in Italy prevented SCD. Interestingly, though, most of the athletic deaths in Italian athletes are traced to anomalies of the coronary arteries.[12]

Pelliccia et al[13] evaluated 1273 athletes in Rome by echocardiography to determine the prevalence of AOCA. In 98.7% of the elite athletes, age 13 to 49 years, from 25 different sports, the origin of the coronary arteries was found to be normal. Variation was seen in 28 athletes, but no abnormal findings were recorded. Based on these results, the authors reported the frequency of AOCA in these elite athletes (notably, many of whom had already been through PPE screening in the Italian sports system) to be <0.1%. These data correlates with research by Zeppilli et al,[14] who found the prevalence of AOCA in 3650 asymptomatic Italian elite athletes screened with transthoracic echography to be 0.09%. Thus, the rarity of this condition, its asymptomatic presentation, and the necessity of diagnosis using echocardiography make the detection AOCA on routine PPE very unrealistic. Basso et al[15] investigated the efficacy of ECG, stress test, and 2-dimensional echocardiography in screening for AOCA as a cause of SCD in 27 athletes. They reported that 10 of the 12 (for whom they had access to prerecorded clinical data) experienced cardiac symptoms, but all had a normal ECG, 2-dimensional echocardiography, and stress test. This study shows that ECG testing for AOCA produces false-negatives, and a normal ECG (at rest or exercise) does not rule out the abnormality. The occurrence of cardiac symptoms experienced by the 10 athletes shortly before sudden death emphasizes the importance of history taking in the PPE, especially focusing on symptoms such as exertional syncope or chest pain. That being said, 15 of 27 (55%) athletes who died had no clinical cardiovascular manifestations or testing during life. Thus, in retrospect, the most appropriate screening methods for this rare and difficult-to-diagnose condition remain uncertain, and the standard PPE (which includes ECG and stress tests in Italy) is limited in its ability to detect AOCA.[13]

In the United States, Maron et al[9] found only 3 cases of SCD in Minnesota high school athletes grades 10 to 12 from 440 schools (deaths recorded by a mandatory state insurance program) over a 12-year period. All 3 occurred in males during exertion; 2 were cross-country/track athletes, and 1 was a basketball player. None of the 3 had symptoms on history or cardiac findings on physical examination. The causes of death included anomalous left main coronary artery from the right sinus of Valsalva, aortic valvular stenosis, and myocarditis. The calculated risk for SCD in study participants (651,695 athletes) over the 12 years was 1:500,000, or 1:200,000 per academic year (0.46/100,000 annually) and about 1:130,000 male athletes. These findings underline the limitations of PPE screening, given the rare occurrence of SCD in these largely healthy athletes and the low potential for impact on outcome.

Effectiveness of Cardiovascular Screening Tests

Table 5 summarizes the available type II original studies that report the sensitivity and specificity of various cardiac screening tests (by comparing them to echocardiography). These studies attempt to evaluate history, physical examination, and/or ECG for detection of cardiovascular disease that may predispose athletes to SCD.[15–19]

Due to a paucity of evidence and conflicting results, drawing conclusions on the sensitivity of the PPE for detecting potentially lethal cardiovascular diseases utilizing ECG is difficult and often confusing. The AHA guidelines do not advocate the use of ECG in mass screening in the United States; however, in Italy, ECG and exercise stress tests have been and integral part of the mandatory screening protocol of elite athletes for years.[2,12–14] These differences in approaches are provocative and indicate that consensus regarding the sensitivity and specificity of various cardiovascular screening tests to detect occult cardiovascular disease has not been achieved.

For example, ECG and/or limited echocardiography have been indicated for use in mass high school and college screening procedures by some authors,[12,14,16,18,20–22] but not by others.[15,17,19,23] Waller et al[10] suggest that limited 2-D screening echocardiography at a cost of $25 each would have been cost effective in recognizing cardiac disease in cardiac related deaths in young athletes. In contrast, Lewis et al[23] studied the efficacy of 2-dimensional and M-mode echocardiography in screening 265 Howard University athletes, 99% of whom were of black ethnicity. Of these athletes, 11% exhibited LV thickness >13 mm, considered to be a possible consequence of training but indistinguishable from mild forms of HCM.

One major difficulty in screening athletes for cardiovascular disorders is the physiologic cardiac adaptations that oc-

TABLE 4. Causes of SDC in Young Athletes Reported in the Literature

Author	Journal	No. Subjects: Age Range	Causes SCD
Maron	*Circulation,* 1980	29: 13–30 y	HCM 48% AOCA 14% CAD 10% Aortic rupture 7% None identified 1%
Waller	*Heart,* 1985	15: 13–29 y	Unknown 53% HCM 21% AOCA 13% Valvular 13%
Maron	*J Am Coll Cardiol,* 1998	3: 16–17 y	AOCA 33% Aortic stenosis 33% Myocarditis 33%
Maron	*JAMA,* 1996	134: 12–40 y	HCM 36% AOCA 13% ?HCM 10% Ruptured aortic aneurysm 5% Aortic stenosis 4% Myocarditis 3% IDC 3% MVP 2% CAD 2% Long QT 0.5% Normal 2%
Waller	*Clin Cardiol,* 1992	14: 14–61 y	CAD 64% AOCA 14% Myocarditis 1% HCM 1% MVP 1%
Corrado	*N Engl J Med,* 1998	49: 11–35 y	ARVD 22% CAD 18% AOCA 12% HCM 2%

ARVD, arrhythmogenic right ventricular dysplasia; CAD, coronary artery disease; HCM, hypertrophic cardiomyopathy, IDC, idiopathic dilated cardiomyopathy; MVP, mitral valve prolapse.

cur in response to high-volume athletic training. This phenomenon, appropriately termed *athlete's heart*, produces increased cardiac mass and left ventricular wall thickness—findings hardly discernible from the changes seen in pathologic HCM. In HCM, the heart chambers may be dilated in addition to being hypertrophied, yet the question still remains as to whether or not some athletes with these changes may actually have a mild form of HCM. A gray zone exists in defining and differentiating athlete's heart from HCM, which makes screening difficult.

Electrocardiogram and even echocardiography have high false-positive results in this regard,[3,20,23,24] as physiologic hypertrophy of 13 to 15 mm (13 mm is often used as a cutoff for normal left ventricle wall thickness) may be interpreted as a mild form of HCM. Many athletes have been found (on echocardiography) to exceed this cutoff minimally without having other signs of HCM.[17,23] Athletes who exhibit increased left ventricle wall thickness tend to be black males participating in sports such as football[17] and rowing.[23] It is still unclear as to whether these changes result from a milder expression of hypertrophic cardiomyopathy, and at which cutoff measurement this could be the case.

Devlin and Ostman-Smith[20] addressed this issue in a small study (sample included 32 athletes, 41 patients with HCM, 66 first-degree relatives and 262 controls). The authors reported that long-axis M-mode and cross-sectional echocardiography could detect HCM versus physiologic cardiovascular training adaptations in athletes. They reported that the best screening measure for HCM was diastolic septum to cavity ratio, with a value of 0.26 yielding a 100% detection rate with no false-positives in the general population. In athletes, these measures yielded a 6% false positive rate with a cutoff of >13 mm for left ventricular wall thickness. Physiologic hypertrophy could then be differentiated from HCM by the absence of

TABLE 5. Cardiovascular Screening Tests Used in PPEs

Parameter Assessed	Author	Evaluation Method	Parameters	Subjects	Characteristics
ECG	Sharma et al[37]	ECG patterns evaluated by cardiologist	12-lead ECG, Hx form, PE by cardiologist	1000 elite junior athletes <18 y; 300 sedentary controls	73% male, mean age 15.7 y (mostly white), from 9 sports, vs. matched controls
ECG	Pelliccia et al[17]	ECG compared to cardiac morphology as seen on 2-D echo, both as seen on 2-D echo, both interpreted blindly	ECGs classified as normal, mildly abnormal, distinctly abnormal: compared to echo for end-diastolic septal wall thickness	1005 elite Italian athletes, mean age, 24 y, from 38 sports	74% male, mostly white, 78% included for PPE, 22% for CVD referral
Cost-effectiveness of ECG	Fuller[35]	Cost-benefit analysis	Assumed all abnormal screen followed by W/U ~$500 ($10/screening ECG); assumed 1/10,000 had undetected CVD	Analyzed cost to screen 700,000 HSA to detect the 70 at risk of SCD	$10/screening ECG, assumed abnormal screen ECG required $365 W/U; assumed abnormal Hx/PE followed by $500 W/U
Combination of Hx, PE, ECG	Fuller et al[18]	Compared ECG to Hx, PE (done by cardiologists) examiners blinded to Hx; echos, stress tests done as indicated by (+) Hx, PE or ECG findings	Positive-cardiac symptoms on Hx, systolic murmur or BP >150/95, ECG with abnormal outcome measures (from 16th Bethesda conference)	5615 high school student athletes	3375 males, 2240 females from 30 selected high schools (near urban centers)
Combination of Hx, PE, ECG	Maron et al[19]	Hx, PE, ECG compared to echo evidence of CVD	If any of Hx, PE or ECG (+), further evaluation by cardiologist done (Hx, PE, ECG, CXR, 2-D, and M-mode echo)	501 University of Maryland student athletes	Age 17–30 y, 71% male, 76% white, from 14 sports (30% football)
Hx, PE, ECG for detecting HCM	Nistri et al[21]	Any positive findings from Hx, PE, or ECG evaluated by 2-D, M-mode echo	HCM = nondilated LV >15 mm, echos read by 3 cardiologists	34,910 Italian military conscripts evaluated in 3 recruiting offices	
Echo, for HCM	Devlin and Ostman-Smith[20]	Compared echos in patients with HCM, relatives of athletes and normal controls	Cardiac wall thickness: diameter seen on M-mode, cross-sectional echo	41 HCM patients, 66 first-degree relatives of those with HCM, 262 normal controls, and 32 athletes	Athletes (runners, rowers, pentathletes weight lifters, all had cardiac hypertrophy) age 14–40 y
Echo in black athletes	Lewis et al[23]	Echo, Hx, PE, ECG	2-D and M-mode echo, Hx, PE and 12-lead ECG	265 Howard University student athletes	99% black, age 18–28 y, 83% men, from 8 sports
Combination of Hx, PE, and echo	Weidenbener et al[16]	2-D echos (at $7.94 per test) done in PPE: additional views, M-mode or Doppler performed as needed	2-D parasternal long and short screening views for 4 CV conditions: HCM, Marfan, aortic stenosis, MVP	Indianapolis high school students	Not documented
ECG, stress test, echo for detecting AOCA	Basso et al[15]	Review of 2 large registries of SCD in young athletes in USA and Italy	27 cases of AOCA as cause of SCD in/after sport participation: 12 had clinical data for analysis	27 cases AOCA in competitive athletes	22 male, 5 female, age 9–32 y, 60% white, 33% black from 10 sports (mostly soccer, basketball) healthy males age 17+ y

TABLE 5. *(continued)* Cardiovascular Screening Tests Used in PPEs

Parameter Assessed	Results	Measurement Characteristics	Conclusions	Application to PPE
ECG	Athletes had sinus bradycardia and arrhythmias more frequently, partial RBBB in 1/3, LVH in 1/2, ST elevation and tall T waves common, but NO HCM	0.4% prevalence of HCM based on ECG criteria only (no echos done)	LVH, ST elevation, peaked Ts common: no W/U needed if asymptomatic; T wave inversions in V2,V3	Study observational and not used to evaluate PPE (no echos were done for false-positive/negative rates)
ECG	(1) ECG abnormal in 40% of 785 PPEs (young male endurance athletes): but only 3% had CV abnormalities; (2) 5% showed bizarre ECG abnormalities with no disease	Sensitivity 51%, specificity 61%, PPV 7%, NPV 96% (for ECG prediction of CVD)	60% athletes in large cohort had normal ECGs, variation in 40% usually due to training changes	False-positives caused by athlete's heart limit ECG usefulness in PPE
Cost-effectiveness of ECG	$0 to screen by AHA Hx/PE; $7.7 million to evaluate the 2.2% with abnormal response; $7 million to screen all with ECG; $40.2 million to evaluate all abnormal ECGs (15.7%)	Sensitivity: AHA Hx/PE 6%, ECG 70%, 2-D echo 80%; specificity: AHA Hx/PE 97.8%, ECG for SCD in HAS 84%, 2-D echo 100%	AHA Hx/PE increases sensitivity to 6%, ECG twice as cost-effective in PPE	Recommend ECG screen as most cost-effective in high school athletes
Combination of Hx, PE, ECG	90% no screen abnormalities by Hx, PE, or ECG; echos done in 10%: 92% normal, 7% minor abnormalities only	Specificity 97.8% for Hx/PE, 97.4% for ECG; ECG false-positive rate 2.6%; 130/146 ECGs done false-positive for LVH, total false-positives 92%	Outcome measures detected in 1/255 athletes, ECG has similar specificity to Hx/PE but more effective as screening tool for serious CV disease	ECG efficiently done on large numbers; recommend ECG once in career of high school athletes
Combination of Hx, PE, ECG	90/501 screen (+): 84% of these normal, 15% mild MVP, 3 athletes ventricular-septal hypertrophy (14–15 mm) indistinguishable from HCM	Specificity 27%, false-positives 15%	Poor sensitivity, no cases of lethal CVD found	Inclusion of ECG as screening test did not increase sensitivity of hex/PE and overall PPE had low sensitivity for lethal CVD
Hx, PE, ECG for detecting HCM	97% (2698/2766) of echos done were normal; 0.7% (19/2698) diagnosed with HCM; 13 diagnosed de novo; 17/19 were asymptomatic	Sensitivity: family Hx 15%, murmur 26%, ECG 68%; specificity: family Hx 98%, murmur 33%, ECG 94%	Screening young healthy males with Hx, PE, ECG (and echo for further W/U) can effectively identify HCM	ECG (with referral to echo) effective in mass screening to identify HCM
Echo, for HCM	Best screen for HCM is diastolic septum: cavity ratio; use contractility measures to differentiate between athlete's heart and HCM	False-positives 6% in athletes, mostly rowers	Systolic LV: cavity ratios >0.63 has 0% false-positives and 100% HCM detection rate	Echo with specific parameters can detect HCM vs. athlete's heart; if used LV wall >13 mm, false-positive rate would have been 16%
Echo in black athletes	99% echos normal; 11% MVP; 11% ventricle septum >13 mm (1/2 of these football players); no lethal CVD found	11% showed increased left ventricle wall thickness, but no HCM found	Echo as primary screen not jusitified, high false-positives in black athletes	Echo not cost-effective in PPE
Combination of Hx, PE, and echo	(1) 64/2997 echos abnormal; 40% of these had (+) Hx and 14% had (+) PE; (2) MVP, bicuspid aortic valve most common abnormalities	Specificity 46%; only 5% (+) PE had abnormal echo; 4% (+) Hx had abnormal echo	Poor correlation for Hx and PE with echo in high school athletes, no HCM found	Authors found cost-efficient method to incorporate echo in PPE, reported poor sensitivity of Hx/PE
ECG, stress test, echo for detecting AOCA	Rest and exercise ECG not helpful		10/12 with clinical data experienced cardiac symptoms, but all had normal ECG, 2-D echo, stress test	Standard PPE limited in ability to detect AOCA

EDV indicates end-diastolic volume; echo, echocardiogram; HSA, high school athlete; LVW, left ventricular wall; MVP, mitral valve prolapse; NPV, negative predictive valve; PE, physical examination; PPV, positive predictive value; RBBB, right bundle branch block; Sx, symptoms; W/U, work-up.

hypercontractility (normal systolic left ventricular wall to cavity ratio, 0.63; 0% false-positives.)

Contributing further to the confusion over appropriate testing methods, various benign abnormalities are commonly found in athletes' ECGs. In a large prospective study, Peliccia et al[17] found variation in normal ECG patterns in 40% of elite Italian athletes, most of which were due to adaptations to athletic training. Larger cardiac dimensions were found to be associated with abnormal ECG patterns such as increased R or S waves, flat or negative T waves, Q waves, left or right axis deviation, left or right atrial enlargement, and sinus bradycardia. ECG changes were more pronounced in endurance sports. They recorded ECG sensitivity at 51% and specificity at 61%, with a positive predictive value of only 7% for true cardiovascular abnormalities. False-positives resulting from athletic adaptations to training were found to limit the usefulness of ECG as a screening tool.

Fuller et al[18] added ECG to the PPE in a station format in screening for common causes of SCD in young athletes. A cardiac technician performed the ECGs on groups of 50 to 300 athletes in PPEs. The results were computer-interpreted and overread by a cardiologist off site. The estimated cost was $10 per ECG. The authors reported a sensitivity of 60% to 70% and a specificity of 97.4% for ECG pick-up of cardiac disease that might predispose to SCD (such as left ventricular hypertrophy associated with HCM, and rhythm abnormalities.) Of the total 660,000 high school athletes screened, ECG detected cardiac disease in 23 of the 33 predicted by history and physical examination. The false-positive rate reported was 2.6%. In large-scale screening efforts, this false-positive rate could translate into considerable added costs (2000 high school athletes in this study were referred for further cardiovascular testing).

In contrast, several studies advocate the efficacy of ECG in large-scale preparticipation screening, especially in detecting HCM. Corrado et al[12] also reported that 75% of the new cases of HCM diagnosed in athletes were diagnosed because ECG was part of the original screening protocol, with referral to echocardiography for positive screens.

Nistri et al[21] also found that ECG proved to be an effective screening tool for HCM. The authors analyzed the efficacy of history, physical examination, chest x-ray, and ECG in screening for HCM in a population of 34,910 male military conscripts in Italy from 1992 to 1996. After a positive initial screen, 2766 recruits were referred for diagnostic echocardiograms. HCM (left ventricle >15 mm) was found in 19 (0.7%), yet 17 of 19 were asymptomatic. All were withdrawn from military duty and were alive and well at 6-year follow-up. The authors reported the sensitivity of ECG as 68% and sensitivity as 94% and advocated that screening with the combination of history, physical examination, and ECG (with referral to echocardiography for suspected cardiovascular abnormalities) could identify HCM in a young, healthy population.

Thus, the literature can establish no consensus as to which screening tests are most effective for detecting cardiovascular risk factors in athletes. ECG in particular is favored by some authors but not others, though poor evidence actually exists for its efficacy. Arbitrary criteria for abnormal ECGs, varying definitions of left ventricular wall thickness/HCM as seen on echocardiogram, variations in testing protocols and sample sizes, and lack of true randomized control trials make it difficult to decipher the discrepancies and variations in the results or to determine an ideal protocol for the cardiovascular portion of the PPE.

Current State of the Preparticipation Evaluation in the United States

Four retrospective cross-sectional reports attempt to assess the completeness of the PPE with respect to inclusion of the formal AHA recommendations for cardiovascular screening in athletes. Three of the 4 observed the PPE process in US high schools athletes and 1 in an NCAA university. All were administered through the athletic director or athletic therapists of the involved schools.[25,26]

In 1 such study, Glover and Maron[26] assessed the adequacy of CV screening in PPEs across 50 states (and the District of Columbia) by comparing the screening procedures to the 1996 AHA consensus and panel guidelines. All 50 states formally required examinations for student athletes, although 8 of them did not actually have an official questionnaire to guide examiners. The authors analyzed the cardiovascular portions of the submitted forms from 43 states that had official questionnaires. Anywhere from 0% to 56% of these forms contained questions specifically recommended for cardiovascular screening. For physical examination, only 5% to 37% of the forms included specific maneuvers directed toward identifying cardiac disease. Blood pressure measurements were not included in the examination in 86% of states. This survey also revealed that 5 of 50 states had absolutely no guidelines or restrictions on PPE examiners, and 11 states actually provided for health care workers with limited or no cardiovascular training, such as chiropractors or naturopaths, to perform the PPEs. None of the 50 states offered standards or qualifications of examiners, and 25 sanctioned nonphysician examiners. Overall, the authors discovered that 40% of state high school associations did not offer standardized PPE forms complying with the AHA recommendations, or had no screening requirement at all.

Other studies report similar findings. Gomez et al[25] found that only 17.2% of high schools used PPE forms with all elements of the cardiac history recommended by the consensus panel, and confirmed that the PPE varies from state to state. However, this study had significant selection and reporting bias, as it was conducted as a mail survey. A sample of 500 from the total population of 2500 athletic trainers registered with the national association was asked to complete a mail survey and submit their PPE forms. A total of 254 trainers responded, and 193 PPE forms were submitted. No outright medical history or examination was required in 7 of these forms: a signature alone from a physician was all that was needed to confirm that the athlete was fit to participate. The authors agreed with the findings of previous research showing that the clinical examination performed in the PPE will closely follow the content of the form, and thus, they advocated the standardization of PPE forms.[27–29]

Koester and Amundson,[30] in a mailed survey analysis of Oregon high schools registered with the Oregon Schools Activities Association, found that 53% of the 142 evaluated forms contained fewer than 5 of the AHA recommendations for cardiac screening. They reported that 42 (27%) of schools were implementing the PPE form that was formally recommended, but not required, by the Oregon Schools Activities Association.

Data on the screening of college athletes are scarce. Pfister et al[6] assessed the cardiac screening methods employed in US NCAA universities between 1995 and 1997. These methods were compared with the 12 AHA recommendations in the 1996 consensus panel screening guidelines. The team physicians or athletic trainers were contacted to elicit the details of scope and format of the PPE. Of the 1110 NCAA colleges and universities surveyed, 879 responded: PPE screening is a requirement at 97%, but only 51% require annual screening. (The AHA currently recommends screening athletes with a history annually and a full history and physical examination as part of a biannual PPE.[2]) Team physicians conducted the screening process in 85% of the on-campus protocols; however, 19% of schools approved screening by nurse practitioners, and 34% had athletic trainers conducting the examinations. Of the 879 schools that responded, 625 reported using a specific PPE form, and only 26% of these contained at least 9 of the 12 AHA screening guidelines. A quarter of the questionnaires contained 4 or fewer of these recommendations. Relevant history questions regarding symptoms of exertional dyspnea, chest pain, and family history of CVD were included in only 40% of the forms. The authors concluded that the cardiovascular screening techniques employed by US colleges were limited in the ability to detect lethal cardiovascular abnormalities that might predispose to SCD in athletes.

These few studies are a start in the analysis of the current state of the PPE, and their results emphasize the lack of standardization of the process, the randomness of the screening methods employed, and the poor adherence to the AHA guidelines for cardiac screening of student athletes. These reports do not begin to answer the question of the most efficacious or appropriate methods of conducting mass PPEs.

A recent trend may be emerging with the use of electronic or Web-based screening questionnaires. Several schools in the United States are moving to online questionnaires for the PPE. Unfortunately, very few have recorded data on the experience.

In 1997 and 1998, Stanford University implemented a Web-based PPE history form, and Peltz et al[31] reported on the development, implementation, and outcome of this process. The questionnaire was programed into the Stanford Web site for athletes to access online and covered medical and musculoskeletal history, eating, menstrual and sleep disorders, stress, and health risk behaviors. The content was validated by 10 sports medicine physicians and 4 epidemiologists and was found to be 97 ± 2% sensitive in detecting positive responses requiring physician attention. The physicians administering the PPE using the questionnaire reported improvement in their ability to provide overall medical care including health issues beyond clearance. The questionnaire allowed a more focused encounter with the physician and decreased the time needed for each examination. Athletes were compliant and found the online history form easy to use. Databases provided by Web-based PPE questionnaires offer opportunities to study trends, risk factors, and results of interventions and improve health maintenance and preventative care for this population of athletes.[31]

Brown University has used a Web-based PPE questionnaire since 2001, and Flore[32] describes the experience in an article in NATA.

A pilot project was also conducted with Ohio high school athletes that demonstrated the ability of a Web-based preparticipation questionnaire to measure the prevalence of positive responses across a variety of health and injury areas.[33]

Hunt[34] also subjectively described the variety in PPE protocols in US high schools and colleges, emphasizing the range from mass station-based examinations, to Web-based, to detailed screens involving pulmonary function tests and echocardiograms. This article reiterates the vast discrepancies in procedure and content of the PPE across the United States.

CONCLUSION

It is hard to find data to support a specific approach to the PPE or to establish best practices for risk factor identification. More research is needed to answer questions and help guide the standardization of the process. For instance, what is the most efficient process for the PPE? Who should conduct the examinations? Where and how should they take place? Is a move to an electronic questionnaire an answer?

A few recent research studies have attempted to document and analyze the PPE process, but few data exist on the current state of the PPE in the United States. The PPE is required by most schools in America but is not implemented adequately, and no standardized format currently exists.

A paucity of scientific data on the PPE makes it difficult to establish conclusions regarding the specific content of the PPE. Lack of a standardized format also makes interpretation of the existing articles difficult. Methods of evaluating the PPE format consist mostly of an assessment on whether the screens included the current AHA guidelines. Thus, conclusions on the validity of the PPE have been based on the inclusiveness of these recommendations, rather than on the effective pick-up rates of these screening methods for cardiovascular disease and risk of sudden death in athletes. The evidence for and against the use of ECG, echocardiography, or exercise testing in mass screening of athletes is conflicting, though generally, in the United States, history and physical examination is the most common method of identifying the rare athlete at risk for SCD.

Further research is needed to establish appropriate methods and formats for the PPE. Standardization of the process is required to establish efficient means to carrying out the AHA guidelines for cardiac screening of student athletes.

The literature presented here is a starting point in the evaluation of the current state of the PPE. More data need to be collected to monitor the screening process of student athletes. Use of a standardized examination in electronic format holds promise for the collection of population-based data to evaluate sensitivity and specificity. The ultimate goal of standardizing the PPE is a challenging yet important outcome for which to strive.

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