Electrocardiography-inclusive screening strategies for detection of cardiovascular abnormalities in high school athletes

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BACKGROUND The best protocol for cardiovascular preparticipation screening (PPS) in young athletes is uncertain.

OBJECTIVE The purpose of this study was to determine the value of integrating electrocardiographic (ECG) testing with standard history and physical examination during PPS to identify potentially serious cardiovascular abnormalities in young athletes.

METHODS A total of 2017 high school athletes seeking clearance for competitive sports were prospectively evaluated using a standardized history and physical examination, 12-lead ECG, and two-dimensional echocardiogram (echo). Primary outcome measures included the identification of cardiac disorders associated with sudden cardiac death. Secondary outcome measures included identification of abnormal, but nonlethal, cardiac conditions that required medical follow-up.

RESULTS Of these athletes, 14.7% had an abnormal history or physical examination and 3.1% had an abnormal ECG based on modern ECG interpretation criteria. Five primary outcomes (1 hypertrophic cardiomyopathy, 4 Wolff-Parkinson-White syndrome) and four secondary outcomes were identified. History and physical examination detected 40% of primary and 50% of secondary abnormalities. ECG detected all five primary abnormalities but none of the secondary abnormalities. Echo was abnormal in 1.2% and detected one primary and four secondary abnormalities. The false-positive rates for primary and secondary outcomes for history and physical examination and ECG were 14.5% and 2.8%, respectively.

CONCLUSION ECG adds value to PPS through increased detection of arrhythmogenic and structural cardiovascular conditions associated with sudden cardiac death. Use of modern ECG interpretation standards allows a low false-positive rate. Routine echo may detect other clinically important cardiac abnormalities, but its role in PPS remains uncertain.

KEYWORDS Sudden cardiac death; Athlete; Electrocardiogram; Preparticipation screening; Echocardiogram

ABBREVIATIONS **AHA** = American Heart Association; **BP** = blood pressure; **ECG** = electrocardiography; **echo** = echocardiography; **EPS** = electrophysiologic study; **HCM** = hypertrophic cardiomyopathy; **IVS** = intraventricular septal; **LVEDD** = left ventricular end-diastolic diameter; **LVH** = left ventricular hypertrophy; **PPS** = preparticipation screening; **PW** = posterior wall; **SCD** = sudden cardiac death; **WPW** = Wolff-Parkinson-White

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Sudden cardiac death (SCD) is a devastating but potentially preventable event in young competitive athletes. Consequently, preparticipation screening (PPS) for early identification of at risk athletes is supported in both the United States (US) and Europe.[1–8] The incidence of SCD varies widely, with estimates ranging from 1:23,000 to 1:300,000 athletes per year.[1,5,9–12] Early studies in the United States relied solely on newspaper and media reports for case identification, which likely underestimated the incidence of SCD. A recent study of National Collegiate Athletic Association athletes using an internal reporting mechanism found an overall incidence of SCD of 1:43,770 athletes per year, with higher risk in males and African American athletes.[13] Although this study was limited to collegiate athletes, it suggests that the incidence of SCD may be higher than previously reported in young athletic populations.

The current US standard PPS as recommended by the American Heart Association (AHA) consists of a personal history, family history, and physical examination, but it lacks sensitivity to reliably detect the majority of athletes with at risk conditions.[7] Indeed, deaths from SCD usually are the result of unsuspected cardiovascular abnormalities and frequently go undetected by the traditional preparticipation

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history and physical examination.[4,14,15] In a retrospective study of 134 athletes with SCD, <5% had a confirmed cardiovascular diagnosis after screening with history and physical examination.[4]

The sensitivity of PPS can be improved with the addition of electrocardiography (ECG) and/or echocardiography (echo). Studies in the United States have shown that the addition of ECG to the standard preparticipation evaluation will increase detection of significant cardiac pathology not discovered by history and physical examination alone.[16–18] In a long-term experience in the Veneto region of Italy, a screening strategy inclusive of ECG reduced the incidence of SCD by 90%, primarily by early identification of cardiomyopathy.[19] One study based in Israel failed to show a benefit for screening athletes with ECGs; however, the results may have been compromised by methodologic flaws, such as the retrospective search of only two newspapers as the only method for identification of outcomes.[20] Arguments have also been made for the addition of echo to PPS because of its ability to detect subclinical structural cardiac abnormalities early in their natural history,[21–25] but research into the risks and benefits is limited. Based on the perceived benefits, the addition of ECG to PPS is now a standard screening practice implemented by major US professional sports and is recommended by international organizations including the International Olympic Committee,[26] European Society of Cardiology,[8] and the Fédération Internationale de Football Association.[27]

Despite the recommendations by these groups, concerns exist that inclusion of ECG in PPS will lead to a higher false-positive rate, unnecessary secondary testing, adverse psychological consequences, and increased health care costs.[28–32] As a result of these concerns and the current lack of a physician infrastructure capable of accurate ECG interpretation in athletes, most high school athletic PPSs consist only of a history and physical examination. The purpose of this study was to compare the findings of the standard history and physical examination and 12-lead resting ECG individually and as an integrated screen (history and physical examination plus ECG) to identify potentially serious cardiovascular abnormalities in a large, diverse population of high school athletes undergoing PPS.

Methods

Study design

This prospective study evaluated the prevalence of cardiac conditions in athletes at two large PPS events in June 2010 and June 2011. All athletes underwent a screening evaluation that included (1) a personal and family history with physical examination; (2) ECG; and (3) limited echo. Athletes with abnormal screening results were followed until a definitive diagnosis was made. The study was approved by the Institutional Review Board of Carolinas Healthcare System, and all participants provided written consent.

Subjects

Participants were rising 10th-, 11th-, and 12th-grade male and female athletes, ages 14 to 18 years, from diverse socioeconomic and racial backgrounds representing all 18 Charlotte Mecklenburg County (North Carolina) high schools. Athletes were defined as those seeking medical clearance to play competitive sports as required by the North Carolina High School State Athletic Association. A total of 2017 high school athletes were screened. Two subjects with known cardiovascular pathology were excluded from the study before being screened.

Outcome measures

The primary outcome measure was identification of a cardiac disorder associated with SCD. The secondary outcome measure was any abnormal cardiac condition that required medical follow-up but did not pose a risk for SCD.[33]

Data collection

Screening PPS questionnaire

Each student completed the standardized Student-Athlete Pre-Participation Form, which is required by the state of North Carolina (see Online Appendix 1). The form includes a section on personal and family cardiac history that is based on the 12-element screen recommended by the AHA.[7] A clinical nurse reviewed the history form and clarified any "yes" responses to the cardiac elements. After confirmation by the clinical nurse, one or more "yes" responses were considered a positive history screen.

Physical examination

Each student underwent a cardiovascular examination based on the AHA recommendations, including (1) blood pressure (BP) measurement; (2) auscultation of the heart while standing, supine, and with Valsalva; (3) palpation of femoral and radial pulses; and (4) inspection for physical stigmata of Marfan syndrome.[7] Any abnormal cardiovascular examination finding was considered a positive screen.

Intake BP measurements were taken in the right arm and were considered elevated if > 90th percentile for a student's age, sex, and height based on the National Heart, Lung, and Blood Institute's Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents.[34] Athletes with elevated intake BPs underwent repeat measurements at checkout after sitting and resting for at least 5 minutes. If a BP measurement remained >90th percentile at checkout, then this was considered a positive screen on physical examination and medical follow-up was arranged. Participation decisions for athletes with isolated BP elevation and an otherwise normal screen were based on the National Heart, Lung, and Blood Institute Report: prehypertension and stage I hypertension were cleared for sports, but stage II hypertension required further evaluation before clearance.[34]

Electrocardiogram

Every student underwent a resting 12-lead ECG with standard lead placement by a cardiac technician. Each ECG was analyzed by a board-certified cardiologist and primary care