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Optimal Screening Methods to Detect Cardiac Disorders in Athletes: An Evidence-Based Review

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Clinical Question: Which screening method should be considered best practice to detect potentially lethal cardiac disorders during the preparticipation physical examination (PE) of athletes?

Data Sources: The authors completed a comprehensive literature search of MEDLINE, CINAHL, Cochrane Library, Embase, Physiotherapy Evidence Database (PEDro), and SPORTDiscus from January 1996 to November 2014. The following key words were used individually and in combination: *ECG, athlete, screening, pre-participation, history,* and *physical*. A manual review of reference lists and key journals was performed to identify additional studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed for this review.

Study Selection: Studies selected for this analysis involved (1) outcomes of cardiovascular screening in athletes using the history, PE, and electrocardiogram (ECG); (2) history questions and PE based on the American Heart Association recommendations and guidelines; and (3) ECGs interpreted following modern standards. The exclusion criteria were (1) articles not in English, (2) conference abstracts, and (3) clinical commentary articles. Study quality was assessed on a 7-point scale for risk of bias; a score of 7 indicated the *highest quality*. Articles with potential bias were excluded.

Data Extraction: Data included number and sex of participants, number of true- and false-positives and negatives, type of ECG criteria used, number of cardiac abnormalities, and specific cardiac conditions. The sensitivity, specificity, false-positive rate, and positive predictive value of each screening tool were calculated and summarized using a bivariate random-effects meta-analysis model.

Main Results: Fifteen articles reporting on 47 137 athletes were fully reviewed. The overall quality of the 15 articles ranged from 5 to 7 on the 7-item assessment scale (ie, participant selection criteria, representative sample, prospective data with at least 1 positive finding, modern ECG criteria used for screening, cardiovascular screening history and PE per American Heart Association guidelines, individual test outcomes reported, and abnormal screening findings evaluated by appropriate diagnostic testing). The athletes (66% males and 34% females) were ethnically and racially diverse, were from several countries, and ranged in age from 5 to 39 years. The sensitivity and specificity of the screening methods were, respectively, ECG, 94% and 93%; history, 20% and 94%; and PE, 9% and 97%. The overall false-positive rate for ECG (6%) was less than that for history (8%) or PE (10%). The positive likelihood ratios of each screening method were 14.8 for ECG, 3.22 for history, and 2.93 for PE. The negative likelihood ratios were 0.055 for ECG, 0.85 for history, and 0.93 for PE. A total of 160 potentially lethal cardiovascular conditions were detected, for a rate of 0.3%, or 1 in 294 patients. The most common conditions were Wolff-Parkinson-White syndrome (n = 67, 42%), long QT syndrome (n = 18, 11%), hypertrophic cardiomyopathy (n = 18, 11%), dilated cardiomyopathy (n = 11, 7%), coronary artery disease or myocardial ischemia (n = 9, 6%), and arrhythmogenic right ventricular cardiomyopathy (n = 4, 3%).

Conclusions: The most effective strategy to screen athletes for cardiovascular disease was ECG. This test was 5 times more sensitive than history and 10 times more sensitive than PE, and it had a higher positive likelihood ratio, lower negative likelihood ratio, and lower false-positive rate than history or PE. The 12-lead ECG interpreted using modern criteria should be considered the best practice in screening athletes for cardiovascular disease, and the use of history and PE alone as screening tools should be reevaluated.

Key Words: electrocardiogram, sudden death, risk management

COMMENTARY

In February 2012, the National Athletic Trainers' Association (NATA) released a position statement[1] addressing prevention strategies for sudden death in athletes. The position statement[1] outlined several common conditions that can result in death in organized sports, including sudden cardiac arrest. In addition, the document outlined screening recommendations for preparticipation examinations, one of which was "a standardized history form" with emphasis on previous symptoms of chest pain or syncope or a personal history of cardiac arrest or a family history of cardiac arrest or sudden death.[1] Additionally, the NATA position statement recognized that the best screening methods for sudden cardiac death have been debated. The most recent recommendations from the NATA,[1] as well as

the American Heart Association,[2] suggested that a complete history and a physical examination (PE) should be completed. Despite such recommendations, these screening methods lack the sensitivity to detect lethal cardiac abnormalities: as many as 80% of patients who experienced sudden cardiac death were asymptomatic until the event occurred.[3] The NATA position statement[1] indicated the need for continued research on cardiac screening methods to improve the ability to identify at-risk individuals in a cost-effective manner and noted that any screening method needs to have an acceptable false-positive rate. In general, the Inter-Association Task Force for Preventing Sudden Death in Secondary School Athletics Programs[4] cautioned against using the ECG as a screening method unless the athlete had been identified as high risk. Furthermore, a working group for the National Heart, Lung, and Blood Institute[5] called for research to be conducted on an ethnically diverse group regarding the sensitivity and specificity of the history and PE and the incremental value of the ECG. This systematic review and meta-analysis[6] of 47 137 ethnically diverse athletes from different age groups answers that call.

Currently, the NATA recommends ECGs in clinical practice only for high-risk athletes.[1,7] Unfortunately, 75% of the deaths during National Collegiate Athletic Association (NCAA) sport participation resulted from a cardiovascular condition.[8] Consequently, the current recommendations for preparticipation examinations and disqualification of athletes with cardiovascular abnormalities are not preventing sudden death. Based on literature from the 1980s, the NATA position statement on preparticipation examinations[7] noted that the annual sport physical was the only source of a medical evaluation for 30% to 88% of secondary school athletes. We must also reflect on the current structure of preparticipation examinations in sports medicine that rely heavily upon recall of the student and parent or legal guardian.[7] With the continually changing family structures in the United States (eg, adoptions, sperm and egg donors, children of immigrants, dysfunctional families), accurately obtaining the athlete's health history, and specifically the history of cardiac conditions on both the paternal and maternal sides, is challenging.

An ECG should be included in the preparticipation examination as a risk-management procedure. The National Heart, Lung, and Blood Institute[5] stated that stakeholders and policy makers should be informed about measures to prevent sudden cardiac death, especially in the pediatric athlete. After suggesting ECGs for male basketball players in March 2015, the chief medical officer of the NCAA[9] quickly retracted his position when approximately 100 team physicians protested the recommendation based on infrastructure and concerns about insufficient evidence. Although the NCAA does not require or recommend ECGs for screening, the outcomes from this systematic review suggest that further emphasis on the use of this tool to prevent sudden death across all levels of participation may be warranted.

Compared with musculoskeletal conditions and concussions, the prevalence of premorbid cardiac disorders is low. However, the risk of death associated with sudden cardiac arrest is much higher than that for musculoskeletal conditions or concussion. As a result, clinicians should be mindful of the risk of negligence litigation that could arise from inadequate screening in the preparticipation examination.

In fact, victims of sudden cardiac death have a larger number of *years of potential life lost* (YPLL), which is a measure of the years lost compared with the standard predetermined age of the society.[10] The YPLLs for both male (2.04 million YPLL) and female (1.29 million YPLL) victims of sudden cardiac death are greater than for all individual cancers.[10] This indicates that cardiac abnormalities occur at an early stage in an individual's life and typically result in sudden death, thereby contributing to the staggeringly high YPLL.[10] Currently, there is no common registry for deaths associated with sudden cardiac events.[11] Therefore, tracking YPLL is difficult when examining deaths associated with athletic participation. Previous researchers[11] identified 1866 athletes (average age = 19 years) who sustained sudden cardiac arrest from 1980 to 2006. In this sample, the individual YPLL equaled 56 years per athlete, with a total of 104 496 YPLL for the 1866 tracked individuals.

To prevent cardiac death in athletes, screening methods must be enhanced. This systematic review[6] explored the sensitivity, specificity, false-positive rate, and positive predictive value of history, PE, and ECG in more than 47 000 athletes and answered the call in the NATA statement[1] for additional research. The results of the systematic review and meta-analysis indicated that the ECG was the best screening method.[6] The PE had the lowest sensitivity and highest false-positive rate in ruling out cardiac abnormalities.[6] Screening with history questions alone had low sensitivity and provided a small increase in the likelihood of detecting the disease (positive likelihood ratio = 3.22; 95% confidence interval [CI] = 1.3, 8.01) and a minimal decrease in the likelihood of detecting the disease (negative likelihood ratio = 0.85; 95% CI = 0.68, 1.07).[6] The meta-analysis of pooled data showed that the ECG had high sensitivity (94%) and specificity (93%), combined with a large and often conclusive increase or decrease in the likelihood of detecting the disease (positive likelihood ratio = 14.8; 95% CI = 9.43, 23.16; negative likelihood ratio = 0.055; 95% CI = 0.012, 0.25). These findings provide the framework for recommending that ECGs be included in clinical practice.[6] Specifically, 1 article[12] in the meta-analysis, a 3-year study of US secondary school athletes, demonstrated that the current recommendations of history and PE resulted in higher false-positive rates than the ECG, which had a low false-positive rate. Thus, both secondary school and collegiate athletes may benefit from the results of this systematic review through subsequent policy changes in screening methods.

Although the evidence for the use of the ECG is strong, barriers to performing this test on the student-athlete population include access to trained and skilled clinicians, access to cardiologists, and budgetary constraints. In addressing the need for a cost-effective ECG screening method, previous authors[13] determined that adding an ECG to the preparticipation examination for secondary school and collegiate athletes cost an additional US $89 and

yielded a cost-effectiveness ratio of $42 900 per life year saved. This model identified low up-front costs for the ECG and a high return on investment from years of life saved, resulting in a cost-effective screening method.[13] The NATA position statement on preparticipation examinations[7] presented a similar model and recommended exploring community organizations that offer free or reduced-cost ECGs to improve cost-effectiveness. Although these models of cost-effectiveness for including ECGs are promising, we need to address the financial disparities of government-funded institutions, median community incomes, health and ethnic disparities, and population densities as they relate to the long-term financial benefit of the student-athlete, institution, and community.

Adding an ECG to the history and PE can be likened to the recent requirement that collegiate athletes be screened for sickle cell trait. Initially, institutions and clinics had to address the budgetary concerns of screening their patients, but this screening method is now considered common practice. The same shift in clinical practice can and should occur with the addition of a 12-lead ECG as a highly sensitive screening method to rule out cardiac abnormalities.[1] Even though sickle cell trait testing is less expensive than ECG, athletic trainers and team physicians should consider adding an ECG to the preparticipation examination at the secondary school or collegiate level (or both) to establish a baseline before sport activity in an effort to reduce the long-term likelihood of a sudden cardiac event.

The results of this systematic review and meta-analysis provide clinicians with insight into 3 common screening methods for lethal cardiac disorders in athletes. The need for a cost-effective and highly sensitive screening method is answered with the use of a 12-lead ECG. To prevent sudden death, clinicians should consult with their team physicians to update the preparticipation examination to include the use of a 12-lead ECG test for all secondary school and collegiate athletes.

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