Early Screening for Cardiovascular Abnormalities With Preparticipation Echocardiography: Feasibility Study

Courtney N. Gleason, MD,†‡§ Deanna L. Kerkhof, BS, MPH,‡ Elizabeth A. Cilia, MS, ATC,‡ Maria A. Lanyi, BS,‡ Jonathan Finnoff, MD,¶ Dai Sugimoto, PhD,*§ and Gianmichel D. Corrado, MD*†‡§*

Objective: The traditional history and physical (H&P) is a poor screening modality to identify athletes at risk for sudden cardiac death. Although better than H&P alone, electrocardiograms (ECG) have also been found to have high false-positive rates. A limited portable ECG by a frontline physician (PEFP) performed during preparticipation physical examination (PPE) allows for direct measurements of the heart to more accurately identify athletes with structural abnormalities. Therefore, it is worthwhile to assess the feasibility of incorporating limited PEFP as part of PPEs. The aim of this study was to investigate the feasibility of incorporating limited screening PEFP into routine PPEs.

Methods: Thirty-five Division I male collegiate athletes were prospectively enrolled in the study after informed consent was obtained. Each athlete underwent screening with H&P, ECG, and limited PEFP. The H&P was performed based on the 2007 twelve-element preparticipation cardiovascular screening guidelines from the American Heart Association. The ECGs were interpreted using the 2013 Seattle Criteria. The limited echocardiographic (ECHO) measurements were obtained in the parasternal long axis view. End-diastolic measurements were recorded for the left ventricular diameter (LVD), left ventricular posterior wall diameter (LVPWd), interventricular septal wall diameter (IVSWd), aortic root diameter, and ascending aorta. The length of time of each screening station was recorded and reported in seconds (sec) and compared by one-way repeated-measures of analysis of variance with pairwise Bonferroni correction. A priori alpha level was set as 0.05.

Results: The length of time for screening was significantly shorter with limited PEFP (137.7 ± 40.4 seconds) compared with H&P (244.2 ± 80.0 seconds) and ECG (244.9 ± 85.6 seconds, $P < 0.01$). The screening time did not differ between H&P and ECG ($P = 0.97$). Six athletes had a positive finding in H&P screening and 3 athletes had positive ECG findings. One athlete had both a positive H&P and screening ECG. All 3 athletes with positive ECGs had negative limited PEFP screens. One athlete had a borderline posterior wall thickness (1.49 mm) on the limited screening PEFP evaluation and another was found to have a borderline IVSWd-to-LVPWd ratio (1.28). All 3 athletes with positive ECG findings and both athletes with a borderline finding on limited PEFP were referred for formal evaluation with a cardiologist. None of the 5 athletes were disqualified from competition after cardiac evaluation, but 1 of the athletes with a positive screening-limited ECHO needs annual monitoring.

Conclusions: Incorporating limited PEFP into PPEs has the potential to limit the number of false-positive and false-negative cardiac screens. Limited PEFP was the fastest screening modality compared with traditional H&P and ECG methods. Based on the time-driven activity-based paradigm of cost analysis, limited PEFP as part of the PPE yields the highest value: the most accurate and reliable information and the lowest dollar/time expenditure.

Key Words: screening, cardiovascular abnormalities, preparticipation, echocardiography, feasibility

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From the *Division of Sports Medicine, Department of Orthopedics, Boston Children's Hospital, Boston, Massachusetts; †Harvard Medical School, Boston, Massachusetts; ‡Northeastern University, Boston, Massachusetts; §The Micheli Center for Sports Injury Prevention, Waltham, Massachusetts; and ¶Mayo Clinic Sports Medicine Center, Department of Physical Medicine and Rehabilitation, Mayo Clinic School of Medicine, Rochester, Minnesota.

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Corresponding Author: Gianmichel D. Corrado, MD, Boston Children's Hospital, 319 Longwood Ave, Boston, MA 02115 (Gianmichel.Corrado@childrens.harvard.edu).

INTRODUCTION

Sudden cardiac death (SCD) in athletes is a devastating event that garners significant attention due to the sensational paradox between the concept of a healthy, young, invincible athlete and a silent, abrupt, premature death. Sudden cardiac death is the leading cause of death during exercise with an estimated incidence ranging between 1 in 40 000 and 1 in 80 000 in young athletes.[1,2] According to extensive and replicated research by Harmon and colleagues in National Collegiate Athletic Association (NCAA) athletes, the leading medical causes of SCD are cardiac in origin.[3,4] The best screening method for identifying athletes at risk for SCD is the subject of significant debate.[5,6]

In the United States, the American Heart Association (AHA) and the American College of Cardiology support the traditional history and physical (H&P) examination as the mainstay of screening athletes for the risk of SCD.[7] However, the H&P examination alone has been shown to result in a high number of false-negative and false-positive results putting athletes with detectable cardiac abnormalities at risk for SCD, and subjecting athletes to costly cardiac work-ups and time away from sport, respectively.[5,6,8] The poor negative predictive value and poor positive predictive value render it an ineffective screening modality.[6,8]

The European Society of Cardiology (ESC) and the International Olympic Committee have mandated routine electrocardiogram (ECG) screenings as part of preparticipation evaluation for all competitive athletes as a result of a 25-year state-subsidized national screening program that reduced the annual incidence of SCD in Italy by an estimated 90%.[9,10] Electrocardiogram identifies occult cardiac abnormalities and has improved efficacy of H&P alone in Europe.

The successful use of ECGs has not been replicable in the United States due to significant cost-ineffectiveness as a result of high false-positive rates and the sizeable difference in screening population.[10,11] Additionally, the leading detectable medical causes of death differ between the 2 countries, with arrhythmogenic right ventricular dysplasia/cardiomyopathy topping the list in the Veneto region of Italy, and structural cardiomyopathies in the United States.[10] Other criticisms, including those regarding the design of study of Corrado et al[10,12] and the differential between baseline SCD rates lend to the inability of the United States to reproduce similar results.

New ECG interpretation methods could impact the aforementioned cost projections with their ability to reduce the occurrence of false-positive results.[13–15] Further research is needed to determine how this reduction will influence the cost-effectiveness of ECG screening in the United States. Despite improved interpretation methods, the ability of ECG to detect structural cardiac abnormalities is still limited, and the estimated rate of SCD in NCAA athletes remains almost unchanged since 2005.[4] The AHA has encouraged the investigation of a clinically effective method of screening that can address the remaining shortcomings of the current screening methods while also including a close look at cost-effectiveness.[16]

The use of limited portable echocardiography (ECHO) by a frontline physician (PEFP) in the preparticipation physical examination (PPE) allows for direct measurement of the heart, and may accurately identify patients with structural abnormalities that can result in SCDs. This has been demonstrated using the Early Screening for Cardiac Abnormality with Preparticipation Echocardiography (ESCAPE) protocols, which also showed that limited ECHO measurements by noncardiologist frontline physicians (FLP) were not statistically different from values obtained on formal cardiology ECHO.[17] During the course of the ESCAPE trials, it was noted that the least timely element of the screening protocol was the limited screening PEFP. As time is a major component of cost-effectiveness, it was determined to be worthwhile to study the feasibility of incorporating limited screening PEFP into routine PPEs as it relates to time.

METHODS

Study Design

This study used a cross-sectional design comparing 3 screening methods to identify cardiovascular abnormalities. Athletes who had positive findings were prospectively followed. Approval of the institutional review board was received before starting the study.

Participants

All NCAA Division I male freshman varsity student-athletes at Northeastern University who received routine PPEs on sports medicine day during this given year consented to participate in the study. This included 10 baseball, 7 ice hockey, 10 rowing, and 8 track and field or cross-country athletes; a combination of both strength trained athletes (ice hockey and baseball players, short distance runners) and endurance trained athletes (rowers, long distance runners). Members of the men's basketball and soccer teams were not available to be screened on this mass PPE screening day. The inclusion criteria included being a varsity student-athlete at Northeastern University, at least 18 years of age, and being screened on the mass PPE screening day. There were no exclusion criteria. Written consent was obtained from all participants before participation in this study.

Procedures

Three screening stations were established for the purpose of this study: screening H&P, screening 12-lead ECG, and limited PEFP. The length of time for screening at each station was recorded and reported in seconds. The screening H&P involved a review of the participant's responses to the medical and family history questions and a physical examination. Both procedures were performed by 1 of the 3 sports medicine fellow physicians. The screening 12-lead ECGs were performed by a certified athletic trainer and an undergraduate research assistant. One FLP interpreted all the 12-lead ECGs, in accordance with the 2013 "Seattle Criteria."[18] The screening-limited PEFPs were all performed by the same FLP who completed a weekend course in advanced ECHO training.

There was a sports medicine fellow present at each of the 3 screening stations to measure time for the different screening examinations. For the H&P station, timing commenced when the participant walked into the examination room and ended with the completion of the last component of the physical examination. The H&P was based on recommendations from the AHA. The history focused on personal history of: exertional chest pain/discomfort, unexplained syncope/near syncope, excessive exertional or unexplained dyspnea/fatigue with exercise, prior recognition of a heart murmur, elevated systolic blood pressure, and family history of: premature death, family history of disability from heart disease in a close relative, specific knowledge of certain cardiac conditions in family members (hypertrophic cardiomyopathy (HCM), long-QT syndrome, Marfan syndrome, and arrhythmias). The physical examination focused on heart murmur, unequal femoral pulses, physical stigmata of Marfan syndrome, and brachial artery blood pressure.

At the ECG station, time measurement started when the participant removed his shirt for placement of the ECG leads and ended after the FLP completed the interpretation of the 12-lead ECG. There was no delay between the reading of the ECG and the completion of the print out. The components evaluated on the ECG were based on the 2013 "Seattle Criteria" and included: T-wave inversion, ST-segment depression, pathologic Q waves, left atrial enlargement, left axis deviation/left anterior hemiblock, right ventricular hypertrophy (RVH), ventricular preexcitation, complete right or left bundle branch block, long or short QT interval, Brugada-like early polarization.

Time for the limited PEFP started when the ultrasound probe was placed on the participant's chest and ended when the last of the 5 measurements was obtained. The limited PEFP measurements were obtained in the parasternal long axis view (Figure 1). End-diastolic measurements were recorded for left ventricular diameter (LVD), left ventricular posterior wall diameter (LVPWd), interventricular septal wall diameter (IVSWd), aortic root diameter (AoD), and ascending aorta (AsAo). Cutoff values to rule out HCM on limited PEFP were as follows: LVD <60 mm,[19] IVSWd <15 mm,[20,21] and IVSWd:LVPWd <1.3 in normotensive athletes and <1.5 in hypertensive athletes.[22] Measurements for the AoD and AsAo were also recorded for epidemiological purposes; 39.1 mm was used as a cutoff value for a normal AoD. The cutoff was selected based on guidelines established by a coalition of governing authorities, including but not limited to the American College of Cardiology, AHA, American Association for Thoracic Surgery, and American College of Radiology.[23]

Statistical Analysis

One-way repeated-measure analysis of variance (ANOVA) was used to find mean time differences among the 3 screening stations. To determine significance in pairwise comparisons, Bonferroni post hoc tests were used to adjust inflated *P*-value due to multiple comparisons, and a pairwise comparison using a *t* test were performed. A priori alpha level of <0.05 was used for all analyses. All analyses were performed using SPSS software (IBM Inc, Armonk, NY).

FIGURE 1. Limited ECHO parasternal long axis view. Parasternal long axis view in end diastole allows for direct measurement of the interventricular septal diameter (distance from A to B), left ventricular diameter (distance from B to C), and left ventricular wall posterior diameter (distance from C to D).

RESULTS

Primary Outcomes

Thirty-five Division I male student-athletes enrolled in the study and underwent screening H&P, ECG, and limited PEFP. One-way repeated-measure ANOVA indicated that there was a difference among the 3 screening tests ($P = 0.001$). The pairwise Bonferroni post hoc tests demonstrated that the mean time for limited PEFP was significantly different compared with H&P ($P = 0.001$) and ECG ($P = 0.001$). No difference was present between H&P and ECG ($P = 0.999$) (Figure 2). The length of time for screening was significantly shorter with limited PEFP (137.7 ± 40.41 seconds) compared with H&P (244.2 ± 80.0 seconds) and ECG (244.9 ± 85.6 seconds, $P < 0.01$) (Figure 2).

Secondary Outcomes

Based on screening H&P, screening ECG, and/or screening PEFP, 25 of 35 athletes had negative PPEs (Table). Using the AHA criteria, 6 athletes had positive findings based on H&P, but after further investigation, no athletes were referred for further cardiac evaluation based on a positive H&P alone. Three athletes had positive findings on ECG and all 3 of these athletes were referred for further evaluation by a cardiologist. One of these 3 athletes also had a positive screening H&P. This athlete had a positive screening H&P consistent with a heart murmur and a positive screening ECG consistent for RVH. He had a normal limited screening PEFP. At the time of formal cardiac evaluation, he was found to have a normal ECHO and was cleared for sports participation by the cardiologist. A second athlete had a positive screening ECG showing left axis deviation, and a normal limited PEFP. He was evaluated by a cardiologist and cleared for participation in sports without a formal ECHO. A third athlete, also with ECG findings consistent with left axis deviation and a normal limited PEFP was referred to a cardiologist. Due to issues with the student's insurance coverage, the student did not receive formal ECHO; however, a cardiologist reviewed his ECG and found a left anterior fascicular block. The ECG was classified as benign in the absence of symptoms or physical findings and the athlete was cleared for participation. Another athlete was found to have borderline

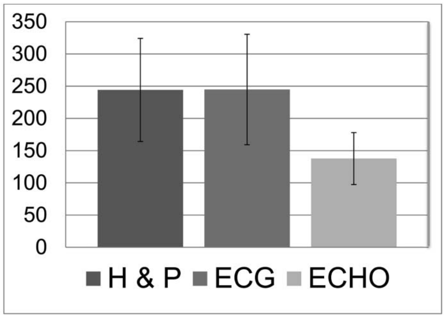

FIGURE 2. Screening time (seconds) for the 3 different cardiac screening methods: H&P, ECG, and limited ECHO. Screening time was significantly shorter with limited ECHO (137.7 ± 40.4 seconds) compared with H&P (244.2 ± 80.0 seconds, $P < 0.01$) and ECG (244.9 ± 85.6 seconds, $P < 0.01$).

TABLE. Screening Medical History, Physical Examination, 12-Lead ECG, and Limited ECHO in Participants With Confirmed Abnormalities

Participants	Limited PEFP Findings	H&P Findings	ECHO Findings	Referral?	Participation Status
1	None	FMH history MI in grandparent	None	No	Cleared
2	None	Heart murmur	None	No	Cleared
3	None	FMH MI	None	No	Cleared
4	None	Borderline	None	No	Cleared
5	None	HTN	None	No	Cleared
6	None	Previous benign murmur	RVH pattern	Yes	Cleared
7	None	None	Left axis deviation	Yes	Cleared
8	None	None	Left axis deviation	Yes	Cleared
9	Borderline posterior wall thickness*	None	None†	Yes	Cleared
10	Borderline IVSWd:LVPWd	None	None	Yes	Cleared. Will be monitored annually

*Secondary to inclusion of a chordae tendineae in the measurement.
†Meets criteria for RVH based on 2010 European Society of Cardiology Criteria but not 2013 "Seattle Criteria."
FMH, family medical history; HTN, hypertension; MI, myocardial infarction.

posterior wall thickness (1.49 mm) on limited PEFP. During the limited PEFP evaluation, it was thought that the borderline thickened posterior wall was likely secondary to inclusion of a chordae tendineae in the measurement. However, the patient also had ECG findings for RVH that would have met the criteria for referral based on 2010 ESC criteria. Therefore, the decision was made to refer the patient for cardiac evaluation. He was found to have a small patent foramen ovale, but otherwise normal formal ECHO confirming the initial suspicion that the thickened posterior wall was a result of including chordae tendineae in the measurement. One athlete had a negative H&P and negative screening ECG, but was found to have a borderline IVSWd-to-LVPWd ratio of 1.28 on limited PEFP. Although this ratio was technically below the 1.3 cutoff, the FLP decided to refer the patient to a cardiologist because he was concerned with the general appearance. He had a formal ECHO performed by a cardiologist that showed he did have borderline left ventricular dilatation. He was cleared for sports participation with annual monitoring.

DISCUSSION

Although the AHA has compelling arguments for recommending its 14-element H&P examination, it is well documented that it has a poor sensitivity and specificity and results in many false-positive screens while failing to identify those athletes who truly are at risk for SCD. The AHA cites many prudent reasons for withholding support of ECG screening as part of PPEs that include "epidemiological, social, [and] economic" considerations.[7] It is estimated that 10 million middle school and high school athletes undergo PPE screening in the United States every year.[7] The AHA estimates a prohibitive cost of national ECG screening at approximately $2 billion dollars per year and a theoretical cost of $3.4 million per one life saved by implementing ECG screening.[7]

Investigations into the feasibility of including a 12-lead ECG into PPEs have historically resulted in a high number of false-positive results. In a study carried out by Malhotra et al[24] in 2011 using the 2010 ESC ECG interpretation standards, ECG screening was positive in 19% of 1473 athletes at the University of Virginia resulting in an additional 359 tests. Only 8 athletes were found to have significant cardiac findings on ECG not detected by H&P.[24] Using the same ECG interpretation method looking at PPE results in 916 athletes, Fudge et al found false-positive rates for history, physical, and ECG to be 31.3, 9.3, and 5%, respectively.[1] In a study on 510 athletes, Baggish et al[25] in 2010 reported that H&P was found to have a false-positive rate of 5.5%.

More concerning than a high number of false positives on H&P and ECG, however, is the evidence suggesting a high rate of false negatives.[5,6] In the same study by Baggish et al in 2010, of the 510 athletes all of whom had baseline ECHOs done as the gold standard, 6 of the 11 athletes identified by ECHO as having cardiac abnormalities with relevance in sports were missed by screening H&P [ie, only 5/11 athletes (45%) with cardiac abnormalities on ECHO were correctly identified with H&P]. Although ECG improved the sensitivity of the PPE compared with H&P alone, 1 of the 11 athletes with relevant cardiac abnormalities was missed by screening with both H&P and ECG.[25] Therefore, 9% of athletes with clinically relevant, known cardiac abnormalities were missed using both screening H&P and ECG.[25] A study by Rowin et al (2011)[26] looking at 114 patients with known HCM also demonstrated the problem of false-negative screening ECGs. Based on the 2010 ESC criteria, 10% of the asymptomatic, but phenotypically affected patients had nonpathologic ECG screens.[26]

Refined ECG interpretation methods including the 2013 "Seattle Criteria" and the 2014 "Refined Criteria" have significantly decreased the occurrence of false-positive and false-negative results. In a study of 1197 predominantly white elite athletes in 2014, Brosnan et al reduced the false-positive rate of ECG screening from 17% to 4.2% using the "Seattle Criteria".[13] Sheikh et al[14] proposed "Refined Criteria" and compared it with ESC recommendations and "Seattle Criteria" in 1208 black athletes and 4297 white athletes. The "Refined Criteria" outperformed both the ESC recommendations and the "Seattle Criteria" reducing false-positive rates in black athletes from 40.4% and 18.4%, respectively, to 11.5%, and in white athletes from 16.2 and 7.1, to 5.3%. Additionally, the "Refined Criteria" significantly improved specificity in both populations without compromising sensitivity.[14] The investigation of the "Refined Criteria" by Riding et al[15] found similar results. False-positive rates in 2491 male athletes (1367 Arabic, 748 black, and 376 white) for ESC, "Seattle Criteria", and "Refined Criteria" were 22.3, 11.6, and 5.3%, respectively. The "Refined Criteria" also improved screening specificity across all ethnicities from 76.6% (ESC) and 87.5% ("Seattle Criteria"), to 94%.

An individual method of screening will not have perfect sensitivity and specificity, or will any combination of methods. Fabrice Muamba received extensive cardiac screening by The Football Association including H&P, ECG, and formal ECHO and was cleared to play, yet suffered cardiac arrest during a football match in 2012.[27] Despite his heart having stopped for 78 minutes, Muamba is one of the few athletes to survive sudden cardiac arrest.[27] Additionally, the leading cause of SCD at autopsy is autopsy-negative sudden unexplained death (SUD), a phenomenon that is simply undetectable because it cannot be explained even after detailed medical investigation.[28]

The motivation behind this study was not to eliminate SCD, but to continue the process of critically examining current PPE practices and evaluating new ideas in an effort to improve the current system. According to the findings of Eckart et al in military recruits, cardiac abnormalities are the leading identifiable cause of sudden death, whereas the leading actual cause of sudden death remains unexplained.[28] Harmon et al[4] found similar results in a 2015 study of SCD in NCAA athletes. The leading medical cause of death was cardiac, which was broken down into specific etiologies. Twenty-five percent of SCDs were categorized as SUD, an undetectable condition. The second leading cause of SCD was a 3-way tie between HCM, cardiomyopathy not otherwise specified, and idiopathic left ventricular hypertrophy (LVH)/possible cardiomyopathy, each responsible for 8%. Conclusively, these conditions, which are all characterized by structural irregularities, cause 24% of SCDs, only 1% fewer than SUD, and can be detected using H&P, ECG, and/or ECHO. Transthoracic ECHO is the gold standard to identify athletes with structural cardiac abnormalities such as HCM and LVH.[25] Limited screening PEFP as part of a PPE can potentially improve false-positive rates from screening H&P and ECG alone and can conceivably broaden the spectrum of disease that can be reliably detected through preparticipation screening to include HCM and other structural abnormalities, which are among the most common causes of SCD.[8,17,29,30]

By definition, HCM is asymmetric LVH. It most commonly involves the septum, but other myocardial segments can be involved as well. The purpose of PEFP during PPE is to screen for structural cardiac abnormalities, such as HCM, to identify athletes who should be sent for formal cardiac work-up, not to diagnose HCM. A septal wall to free wall ratio cutoff of 1.3, ventricular septal thickness of 15 mm or greater, and/or a hypertrophied nondilated left ventricle are not individually diagnostic of structural cardiomyopathies, but should prompt referral to a cardiologist.[31] By convention, ECHO measurements are taken in diastole for 2-dimensional ECHO.[31] The parasternal long axis view is the best view for measuring the left ventricular size and wall thickness,[31] which is "… the most reliable independent criterion to differentiate physiologic from pathologic left ventricular hypertrophy."[20] The obtainment of supplemental information such as the right ventricle and left atria measurements would enhance the reliability and utility of the limited screening PEFP, according to the findings of Caselli et al in 2014, but further research is needed to determine whether the addition of such measurements is possible and cost-effective, especially considering the PEFP is a screening test with the intent of identifying athletes who would benefit from formal ECHO evaluation.[20]

Similar to the study by Wyman et al in 2008 in which cardiologists feasibly condensed a formal ECHO to a 5-minute procedure and incorporated it into PPEs, the results of this study demonstrate that incorporating limited portable ECHO is feasible. The ESCAPE method and this feasibility study is the first in which portable ECHO has been used by FLPs to assess wall thickness in the athlete's heart. Limited PEFP was the fastest screening modality compared with traditional screening H&P and screening ECG by a statistically significant margin.

Secondary outcome measures of this study were also encouraging. Of the 3 athletes with ECG findings that required referral for cardiology evaluation, none had concerning findings on limited screening PEFP and all were cleared for participation by the cardiologist. The false-positive rate for ECG was 8.6%. Additionally, 2 athletes had normal screening H&P and screening ECG, but borderline findings on limited PEFP. One athlete had a borderline thickened posterior wall (1.49 mm) on limited PEFP. The formal ECHO identified a small septal defect, but no abnormal wall thickness. The athlete was cleared by the cardiologist for sports participation. The other athlete with a borderline finding on limited screening PEFP had an IVSWd-to-LVPWd ratio of 1.28 (cutoff > 1.3). This athlete was found to have a borderline dilated left ventricle on formal ECHO, but was cleared for participation by the cardiologist with annual monitoring planned in the future. The athlete with a borderline thickened posterior wall was the only false positive of the limited screening PEFP examination, correlating to a 2.7% false-positive rate. Although the sensitivity and specificity of limited screening PEFP could not be calculated based on this study design, these findings support the hypothesis that limited screening PEFP could help to decrease the number of unnecessary cardiology referrals that result from false-positive findings from screening H&P and ECG. It is possible that the limited screening PEFP may also decrease the number of athletes with true pathology who are missed by the current screening regime, but since just one athlete with borderline structural cardiac pathology requiring only annual monitoring and not immediate disqualification was identified in the current study, further research is required to answer this question.

In a previous study from this institution, Yim et al[17] found "strong interoperator reliability and concordance of measurements of focused echocardiography compared with formal echocardiography." The FLPs trained in ultrasound can perform a limited ECHO, which includes a parasternal long axis view, and obtain measurements important for identifying structural cardiomyopathies. The measurements obtained by FLPs were not statistically different from those obtained by a cardiologist, indicating the measurements were accurate.[17] The ability of FLPs to obtain measurements relevant to HCM is exciting not only because of the potential to possibly save lives through early identification of HCM during PPEs, but also as a new frontier for medical specialties including pediatrics, family medicine, emergency medicine, internal medicine, and all other physicians who are asked to clear young and old potential athletic participants. The journey into this medical arena has already shown that with minimal time and effort these same physicians taught to do the ESCAPE method can look at the aorta and determine its size.[32] As more physicians use this technology, they will be able to assess other cardiac abnormalities, including but not limited to pericardial effusions and valve disorders. In many ways, this technique can be a gateway for new areas of learning for physicians that go far beyond the rubber stamp type H&P.

In the 2007 position statement from the AHA, cost was listed as one of the major obstacles to expanding cardiac screening modalities in conventional PPEs beyond the H&P.[7] By incorporating ECG into standard PPEs, the authors estimated a cost of $330 000 for detecting each athlete with relevant cardiac disease.[7] Recently introduced to healthcare delivery by Kaplan et al,[33] the concept of time-driven activity-based costing is one paradigm for estimating healthcare costs and identifying areas for cost savings. It is based on a 3 pronged approach to identifying the cost of rendered healthcare services: creation of process maps, estimation of costs associated with the provision of specific services, and aggregation of total costs through synthesis of cost and time data.[33,34] Specifically, labor rates for physicians for the time needed to complete an activity are taken into account.[33,34] In this study, performing the limited PEFP proved to be the fastest screening modality compared with H&P and screening ECG. In discussing resource allocation in which a physician's time is directly related to cost, a screening test that takes less of a physician's time is inherently more cost-effective. As stated by Kaplan and Porter, "the proper goal for any health care delivery system is to improve the value delivered to patients. Value in health care is measured in terms of the patient outcomes achieved per dollar expended."[35] Incorporating limited PEFP into routine PPEs is the most cost-effective from a time-driven, activity-based resource allocation perspective when compared with screening H&P and ECG. Additionally, it is also the most high yield of the 3 screening modalities as the "gold standard" for diagnosis of the most common detectable etiologies of SCD in athletes: HCM and other relevant structural cardiac abnormalities.

In addition to the cost advantage of a limited PEFP with allocation of time as a valuable resource, there is also tremendous potential for cost savings by including limited PEFPs in routine PPEs as a way of decreasing the number of athletes referred for formal cardiac evaluations based on false-positive results from screening H&P and screening ECG. Potentially, inclusion of limited PEFP could be a key component of decreasing the number of false-positive results from current screening protocols while also decreasing the number of athletes with true pathology who are missed with the current protocols.

The results of this study are encouraging with regard to finding a reliable, cost-effective solution to the complex clinical problem of identifying athletes at risk of SCD. The limited PEFP performed as part of the PPE, which is the fastest screening modality compared with screening H&P and ECG, may potentially decrease the number of false-positive and false-negative screens common with the current system.

There are identifiable limitations to this study. This was a small study of only 35 athletes, none of whom reside in the highest risk group identified by Harmon et al: black male basketball athletes. Including higher risk groups could prolong the recorded screening time for H&P, ECG, and limited PEFP, as positive screening tests take more time. The secondary outcomes may also be affected, as seen in the study by Sheikh et al[14] where the false-positive and false-negative outcomes were higher in the population of black athletes in comparison with that of white athletes. To truly validate the feasibility and utility of the limited screening PEFP, a multicenter trial must be conducted to increase the power of the sample size and to include all risk groups. The collection of data including race, age, and sport specifics (endurance or strength-based) is pertinent to the validity of such a study, as it is needed to accurately assess both the athletes and the limited PEFP.

There are also identifiable impediments to the translation of this research to clinical practice. Primary care physicians performing most PPEs may not currently feel comfortable performing limited PEFPs in the office. Training for physicians will be required for widespread implementation. Additionally, portable ultrasound machines may not be currently found ubiquitously in all FLP offices. However, portable ultrasound equipment is becoming more commonplace in FLPs' offices, and may increasingly be the standard of care for a multitude of diagnostic purposes. In the coming years, it seems reasonable to predict that most physicians performing PPEs will have access to ultrasound equipment to be used for limited PEFPs and a plethora of other diagnostic modalities. There remains more work to be done in identifying the most effective method for screening athletes for cardiac abnormalities, but limited PEFP as part of routine PPEs is feasible, cost-effective, and most importantly reliable and accurate.[17,33]

CONCLUSIONS

The ECHO is the gold standard for diagnosing structural cardiac abnormalities, which are the leading identifiable causes of SCD and cannot be reliably identified with current screening modalities during the PPE, including the screening H&P and ECG. In addition to allowing for direct visualization and measurements of the heart to accurately diagnose cardiac abnormalities, limited PEFP also requires less time than the screening H&P and ECG. The inclusion of limited PEFP as a pivotal portion of any preparticipation screening could have the potential to dramatically decrease the number of referrals for full cardiac evaluations as a result of false-positive screenings from H&Ps and ECGs. Perhaps even more importantly, limited PEFPs as part of the PPE has the potential to accurately identify athletes with potentially life-threatening cardiac conditions that the H&P and ECG does not identify. Moreover, limited PEFP in PPE offers a significant cost advantage both with regard to physician time, in the concept of time-driven activity-based costing, and cost savings from the decreased number of unnecessary cardiac referrals and subsequent full cardiac evaluations. Including a limited one parasternal view PEFP as part of the traditional PPE solves 2 of the most significant clinical conundrums with regard to PPEs: improved sensitivity and specificity of PPEs and significant cost savings. A PPE that includes a limited PEFP along with other well-proven components of the physical examination and a rhythm strip may very well be the answer to the question: "How do we as healthcare providers best screen athletes at risk for SCD?"

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