An evaluation of an educational program for improving the accuracy of ECG interpretation in athletes by primary care clinicians

Stephen F Segatore

University of Massachusetts College of Nursing

Capstone Chair: Elizabeth A. Henneman PhD, RN

Capstone Committee Member: Pamela Aselton PhD.

Capstone Mentor: Pierre Rouzier MD

Date of Submission: April 23, 2016

Table of Contents

Acknowledgements

This project would not have been possible without the help and support of many people First, I would like to express my gratitude to my mentor Pierre Rouzier MD who offered incalculable support, energy and passion for this topic. The entire staff of University Health Services without their assistance this study would never been completed. Special thanks to Aaron Baggish MD for his insight and guidance during the planning and execution phases of this project were invaluable.

Thank you to my capstone chairs Elizabeth Henneman PhD, RN and Pamela Aselton PhD, RN for your eternal support and encouragement during this process. Your suggestions and wisdom made this project what it is.

Lastly and most importantly, I would like to thank my family for their unending support through this process. To my wife Sue, thank you for doing all the things I could not during this process. I could not have done this without you. To my children for being an endless source of inspiration and humor, thank you.

Abstract

Background: In order to identify athletes at risk for sudden cardiac death (SCD), comprehensive screening that includes ECG interpretation is needed. Many primary care providers, including physicians and nurse practitioners, have reservations about including electrocardiograms (ECG) in the screening process because they lack confidence in their ability to correctly identify normal variants in the ECG of an athlete.

Method: An educational program with previously validated interpretation criteria for normal variants of the athletic heart was presented to providers at a university based healthcare clinic the Northeast. A pre and post design was used to compare the accuracy of ECG interpretation.

Results: A total of 13 providers participated in the study. The educational program increased the accuracy of ECG interpretations. A significant decrease of false positive rates (from 21% +/-14 to 13% +/- 9 (p=0.013) occurred following participation in the educational course.

Conclusions: This study demonstrated the effectiveness of an education intervention in increasing the accuracy of ECG interpretation by primary care providers.

Keywords: sudden cardiac death, athlete, sport, screening, prevention, criteria, electrocardiogram

Background/Problem

Sudden cardiac death (SCD) is a leading cause of mortality in athletes during practice and competition. In these athletes the most common causes of SCD are undiagnosed cardiac abnormalities with hypertrophic cardiomyopathy (HCM) being the most common cause in almost 50% of the cases (Maron, Epstein, & Roberts, 1986; Harmon, et al., 2015). There is considerable international consensus that pre-participation screening (PPS) of athletes prior to practice and competition should take place (Drezner & Corrado, 2011; Asif & Drezner, 2014). However, there is no consensus on the best method for achieving the goal of universal PPS. The current most commonly used method of PPS is the Pre-Participation Evaluation 4th edition, which is composed of a physical exam along with questions regarding family and personal cardiac history (Maron, et al., 2007). However, this method is fraught with limitations including high false positive rates, poor recall of family history, inconsistent physical exam techniques, and symptom minimization on the part of athletes who do not want to be excluded from competition. There is mounting evidence that inclusion of a resting 12 lead electrocardiogram (ECG) to PPS will increase the detection of structural or electrical abnormalities in the athlete thus reducing the incidence of SCD (Drezner, et al., 2012).

Competitive athletes are at higher risk than the general population for SCD (Womack, 2011). The reasons for this are unclear but may have to do with the exertion needed for high-level training and competition (Harmon, et al., 2015). While the actual incidence of exercise related SCD is unknown due to non-uniform reporting guidelines, these deaths have a significant public and personal impact. In order to screen athletes for potential undiscovered cardiac abnormalities that may predispose them to SCD a consistent and accurate method of assessment is required (Corrado, et al., 2005). In the past concerns about limitations in primary care providers experience in ECG interpretation and high false positive rates with ECG inclusion has created a barrier to the adoption of ECG as a standard component of PPS along with the traditionally accepted methods of history and physical exam (Drezner & Corrado, 2011). If we are able to provide primary care providers with an educational program that includes specific ECG criteria for what is a normal variant and what is an abnormal finding in the athlete, we can perhaps improve accuracy rates for primary care providers.

Review of the Literature

A comprehensive search of the literature for evidence addressing the use of ECG in PPS and comparisons to efficacy of PPE-4th included the Cumulative Index of Nursing and Allied Health Literature (CINHAL) and PubMed of the National Library of Medicine. Search terms used were sudden cardiac death, athlete, sport, prevention, screening, electrocardiogram and criteria. These search terms were applied in the search alone or in combination. This search yielded 698 results published between 2005 and 2015. Articles were selected during this period because they would include research undertaken after the publication of the most recent ECG interpretation criteria. Six hundred and eighty-four were deleted for being duplicated in the search, poor research designs, not specifically addressing ECG or PPS, not published in English or abstracts only. 14 case reports, expert opinion, research articles, systematic reviews, and meta-analyses were retained for review. Items selected for review were appraised for quality of evidence using the JHNEBP Research and Non Research appraisal tools.

ECG Correlation to Personal Symptoms

Wilson et al (2008), in a non-experimental observational study (JHNEBP IIIB) confirm the ability of using resting ECG in conjunction with personal symptoms, family history questionnaires and physical examination when conducting PPS. The authors enrolled 2720 participants broken down into two sub groups including 1074 athletes (mean age 15.8 years) and 1646 physically active schoolchildren (mean age 16.1 years). The participants were screened using personal and family history questionnaires, physical examination and ECG. Based on this screening methodology, nine participants with a positive diagnosis associated with SCD were identified. At the time of examination, none of the participants diagnosed with a cardiac anomaly were symptomatic or had a family history of anomalies consistent with SCD. The authors concluded that the use of family history and personal symptom questionnaires alone are insufficient to identify people with the potential for SCD. The authors further assert that the addition of an ECG to the PPS procedure is necessary when screening for potential causes of SCD.

Comparison of PPE-4 and ECG

Dunn et al. (2015) examined in an observational cross section study (JHNEPB IIB) the prevalence of athletes who had a positive screening for cardiac anomaly based on the PPE-4 tool recommended by the American Heart Association (AHA) and then compared those positives with an ECG interpreted with modern ECG criteria. The study enrolled 1,596 participants from the San Francisco, CA area including 297 (167 males; mean age, 16.2 years) high school athletes, 1016 (541 males; mean age, 18.8 years) collegiate athletes, and 283 (mean age, 26.3 years) male professional athletes. All participants were initially screened using personal and family history questions from the AHA 12-elements. After the personal and family histories were obtained all participants had an ECG, which was interpreted using three different sets of interpretation criteria including Seattle criteria, Stanford criteria, and European Society of Cardiology (ESC) recommendations. The authors reported that almost one-quarter of all participants (23.8%) had at least one positive response to the AHA personal and family history elements, with high school and college athletes having at least one positive response (25.9% vs 27.4%), interestingly professional athletes had a considerably lower rate of having at least one positive response (8.8%, $P < 0.05$).

Females reported more episodes of unexplained syncope (11.4% vs 7.5%, $P = 0.017$) and excessive exertional dyspnea with exercise (11.1% vs 6.1%, $P = 0.001$) than males. High school athletes had more positive responses to the family history elements when compared with college athletes ($P < 0.05$). The percentage of participants who had an abnormal ECG varied between Seattle criteria (6.0%), Stanford criteria (8.8%), and ESC recommendations (26.8%). The authors conclude that use of the PPE-4 will lead to an excessive number of participants screening positive for potential cardiac anomalies. Fudge et al. (2014) compared the accuracy of cardiovascular screening inactive adolescents and young adults using the PPE-4 and ECG. Using a prospective non-randomized design (JHNEBP IIB) the participants were prospectively screened using a standardized questionnaire based on the PPE-4, physical examination and ECG interpreted using modern standards in this case the ESC criteria. The participants with abnormal findings had a cardiac echocardiogram and further evaluation. The principal outcomes of the study included disorders associated with SCD. Data was collected from September 2010 to July 2011, a total of 1339 participants were screened.

Participant demographics included: age 13-24 (mean 16) years, 49% male, 68% Caucasian, 17% African-American and well over half 1071 (80%) participated in organized sports. Over half 916 (68%) of the questionnaires contained an abnormal response. The participants with an abnormal response to the questionnaires had a physician review the responses with the participants. After the physician review, slightly over half of the abnormal response participants 495/916 (54%) were thought to have non-cardiac symptoms and/or a benign family history and did not warrant additional evaluation. Physical examination was abnormal in 124 (9.3%) participants, and 72 (5.4%) had ECG abnormalities. Echocardiograms were performed in 586 (44%) participants for abnormal history (31%), physical examination (8%) or ECG (5%). Five participants (0.4%) were identified with a disorder associated with SCD, all with ECG-detected Wolff-Parkinson-White. The false-positive rates for history, physical examination and ECG were 31.3%, 9.3% and 5%, respectively. This study resulted in similar results to Wilson et al. (2008) and Dunn et al. (2015) that the standardized history and physical examination using the PPE-4 yields a high false-positive rate in a young active population with limited sensitivity to identify those at risk for SCD.

Meta-analysis

Harmon, Zigman & Drezner (2015) conducted a systemic review with meta-analysis (JHNEBP IA) of the available data to compare PPS strategies. The resulting data was assembled and analyzed for sensitivity, specificity, false positive rates and positive and negative likelihood ratios. In all the authors included fifteen articles reporting on 47,137 athletes. After meta-analysis the sensitivity and specificity of ECG was 94%/93%, history 20%/94%, and PE 9%/97%. The overall false positive rate of ECG (6%) was less than that of history (8%), or physical exam (10%). Positive likelihood ratios were ECG 14.8, history 3.22 and PE 2.93 and negative likelihood ratios were ECG 0.055, history 0.85, and PE 0.93. There were a total of 160 potentially lethal cardiovascular conditions detected for a rate of 0.3% or 1 in 294. The most common pathologies were Wolff-Parkinson-White (67, 42%), Long QT Syndrome (18, 11%), hypertrophic cardiomyopathy (18, 11%), dilated cardiomyopathy (11, 7%), coronary artery disease or myocardial ischemia (9, 6%) and arrythmogenic right ventricular cardiomyopathy (4, 3%). As with all previous studies reviewed above these authors, conclude based on meta-analysis that the operative strategy for screening for cardiovascular disease in athletes is ECG. The authors assert that ECG is five times more sensitive than history, ten times more sensitive than physical exam, has higher positive likelihood ratio, lower negative likelihood ratio and a lower false positive rate. The authors conclude that an ECG interpreted using modern criteria should be considered best practice in screening for cardiovascular disease in athletes while the use of history and physical alone as a screening tool should be reevaluated (Harmon, Zigman, & Drezner, 2015).

Accuracy of ECG in PPS

Drezner et al. (2012), in a non-randomized trial, (JHNEBP IIB) examined the interpretation of ECG before and after the introduction of interpretation criteria. A total of 60 physicians in several specialties and stages of training including primary care residents (n=22), primary care attending’s (n=6), sports medicine (n=12) and cardiologists (=10) participated. They were asked to interpret 40 ECGs (28 normal and 12 abnormal) and classify them as either 1) normal- no further testing, or 2 abnormal -further evaluation and testing needed. After the initial interpretations were completed, the participants were given a set of ECG interpretation criteria and then reinterpreted the ECGs in light of the provided criteria.

Prior to the implementation of the interpretation criteria, the total number of ECGs correctly interpreted were primary care residents 73%, Primary care attending's 73%, sports medicine physicians 78% and cardiologists 85%. After the implementation of the ECG criteria, all physician groups significantly improved their accuracy (p<0.0001): primary care residents 92%, primary care attending's 90%, sports medicine physicians 91% and cardiologists 96%. The use of the ECG criteria tool increased, specificity from 70% to 91%, sensitivity from 89% to 94% and there was no difference comparing cardiologists versus all other physicians (p=0.053). The authors conclude that use of standardized criteria significantly improves accuracy in interpretation.

Prevalence of ECG abnormalities

Brosnan et al. (2014), in a prospective cohort study (JHNEBP IIB) sought to first identify the prevalence of ECG abnormalities in a cohort of elite athletes in their region of Australia based on the European Society of Cardiology (ESC) criteria and to determine if application of the Seattle Criteria reduced the number of athletes with ECG changes considered abnormal. From 2011 to 2012, of the 1197 athletes who underwent screening, 119 met exclusion criteria leaving 1078 participants. The exclusion criteria for participants were age < 16 or > 35 or a history of known cardiac abnormality. The results of the study revealed 186 (17.3%) had an abnormal ECG according to ESC recommendations and a further 30 (2.8%) had unclassified changes. Three athletes (0.3%) were found to have a cardiac abnormality on further investigation. Using the Seattle Criteria, the number of athletes classified as abnormal fell to 48 (4.5%, p<0.0001) and the three with an underlying cardiac abnormality were still identified. The authors concluded that the Seattle Criteria decreased the false positive rate while at the same time identifying the athletes with true cardiac abnormalities.

In a randomized controlled trial (RCT) (JHNEBP IB) Exeter et al, (2014) endeavored to replicate the Drezner et al (2012) study. Exeter et al (2014) in an effort to clarify if learning effect biased the earlier Drezner et al (2012) employed a RCT with an intervention group (interpretation tool) and control (no use of interpretation tool). The study group was made up of 62 physicians, with a mean time in practice of 16 years. They were randomized to intervention and control groups. The participants interpreted 10 baseline and 30 post-randomization athlete ECGs. The authors reported that intervention participants were more likely to be correct than the control group: OR 1.72 (95% CI 1.31 to 2.27, $p<0.001$). Correct ECG interpretation was higher in the intervention group, 88.4% (95% CI 85.7% to 91.2%), than in the control group, 82.2% (95% CI 78.8% to 85.5%; $p=0.005$). Sensitivity was 95% in the intervention group and 92% in the control group ($p=0.4$), with specificity of 86% and 78%, respectively ($p=0.006$). There were 36% fewer false positives in the intervention group ($p=0.006$). The authors concluded that the inclusion of standardized ECG interpretation criteria lowers false positive rates.

Psychological Consequences of ECG testing

Maron et al. (2007), Estes III and Link, (2012), Link and Estes III, (2012) have raised the question of the psychological effects of the exclusion of athletes based on the potential of a false positive on a PPS with ECG. In a later study, Asif et al. (2014) conducted a prospective non-RCT (JHNEBP IIB). One group received the standard PPE- 4 (control) and the other received the PPE-4 and ECG (experimental). A total of 952 athletes participated (150 control, 802 experimental) of these 4.4% worried about having a cardiac condition compared to 73% who wanted to learn if they had a cardiac condition prior to competition. Compared to the control group those who received ECG were more likely to feel safer during completion and support all athletes receiving ECG. The authors conclude that using anxiety should not be used as a reason not to have ECG screening of athletes.

Synthesis / Conclusions

All of the reviewed papers supported the inclusion of ECG in PPS as the best practice available. If a national recommendation for inclusion of pre-participation ECG in the US is to be made, a larger group of qualified primary care providers must be trained. The need exists for primary care provider training in modern ECG interpretations, which distinguish normal physiologic variations of the athletic heart from abnormalities relating to pathology (Drezner et al. 2013). The feasibility of implementing the Seattle Criteria and an associated online educational program in a primary care setting with both physician (MD) and nurse practitioners (NP) is both needed and easily completed. An examination of providers' interpretation skills and comfort level should increase with the implementation of the educational program for providers. This educational program will lead to increased detection of cardiac abnormalities in pre-participation ECG screenings.

Theoretical Framework

All of the participants in this project were primary care providers both, NP and MD. Given the age and educational level of the participants, the adult learning theory was used as a framework to implement this project. In his seminal work, Lindeman (1926) described the basic principles of adult learners; later Knowles (1998) expanded upon these principles. The basic assumptions of adult learning theory fall into five domains. 1. Adult are motivated to learn as they experience needs and interests that learning will satisfy. 2. Adult orientation to learning is life centered. 3. Experience is the richest source for adult learning; thus adult learners should reflect on their experiences as they relate to the topic being taught. 4. Adult have deep need to be self-directing. 5. Individual differences among people increase with age; therefore, these differences must be accounted for in the presentation of the material to be learned.

The DNP student made sure that the educational program designed for this project accounted for all of the adult learner assumptions. It is important to relate the importance of the subject matter to the needs of the adult learner (Knowles, 1998). In order for the educational project to be successful awareness of the conditions in which adult learners are best taught was necessary. Knowles (1998) proposes six domains in which adults learn best 1.) Adults feel the need to learn and have input into what, why and how they will learn. 2.) The content and process of learning bear a meaningful relationship to experience. 3.) What is being learned relates to the individuals' tasks and goals. 4.) The adult learner needs autonomy and that autonomy is congruent with the learning method employed. 5.) The learning environment minimizes and encourages freedom of experimentation. 6.) The individual learning styles of the participants must be taken in to account. Based on these constructs an educational program will be selected that will endeavor to satisfy as many requirements as possible of adult learning theory.

Project Design, Methods, Implementation

Population Description and Organizational Analysis

The project was conducted in a university based healthcare clinic in the Northeast that provides primary care in both adult and pediatrics. There is an onsite pharmacy, physical therapy clinic as well as eye clinic and onsite radiology. An urgent care clinic on site provides care for urgent but not emergent medical issues and has a referral agreement with a local hospital for transport of patients with acute care issues. An organizational scheme of medical director / executive director leadership with provider input as to the running of the practice is present. There are 17 providers on staff with ten MDs including three sports medicine providers, two pediatricians, and six internal medicine as well as six family nurse practitioners (FNPs). The facility serves the campus wide community including students, faculty and staff as well as varsity athletes as a provider of primary and urgent care. The campus is made up of 28,518 students (22,134 undergraduates and 6,384 graduate) of these 68.3% are white, 7.9% Asian, 4.9% Latino and 3.7% African American / Black. The central clinic houses the sports medicine clinic (SMC), the primary site for treatment, and follow up of sports and orthopedic injuries on campus.

Stakeholder Support

Several stakeholders benefited from the implementation of this educational project. The key stakeholders were the primary care providers in the practice resulting from their direct participation in the project. Secondary stakeholders are future athletes who need PPS prior to participation in sports. The final stakeholders are the larger community of primary care providers. Results from this study may change the role of NP in PPS.

Resources, Constraints, Facilitators and Barriers

The majority of resources for this project were in place within the facility offices. This project utilized an online learning platform with each participant/provider having access to a computer where a didactic education session on ECG interpretation was provided.

An invitation letter was hand delivered by the DNP student to eligible participants which allowed for ensured receipt of the invitation letter as well as providing a chance to ask any questions about participants' roles in the project. Implementation was facilitated by the strong professional relationship that had developed between the DNP student and the providers at the clinic. A barrier to completion was the amount of time each participant had to invest in the project. Approximately ten hours in total was needed to complete the pre education questionnaire, pre education ECG interpretation, online education program and then post education questionnaire and ECG interpretation.

Goals, Objectives, and Expected Outcomes

The goal for this project was to increase ECG interpretation accuracy. The providers were asked to assess 40 ECG and classify them as clear to compete or refer to further workup. Then the participants completed a six-hour online education course related to interpretation of ECG in athletes. After completion of the education program the providers were asked to reinterpret the ECG as before and improvements in interpretation and reduction of false positives will be the outcome measures. The goal for the project was a 90% completion rate. Specific statistical tests used were descriptive statistics and paired t tests to assess pre and post intervention changes in accuracy.

This educational project utilized a Plan-Do-Study-Act (PDSA) model (Speroff & O'Connor, 2004). The “Plan” portion of the project began with discussions assessing the feasibility of the project and if the requisite ECGs would be available for use. The next step undertaken was obtaining Institutional Review Board (IRB) approvals for the use of human subjects in the study. The "DO" were teaching the providers about the importance of incorporating ECG in the PPS process through didactic sessions. The "Study" portion of the project compared the interpretations of the ECGs from the pre education program and utilizing a online education program with a follow up post education program to assess for differences in accuracy in ECG interpretation. The "Act” compared the data acquired from this project to other projects completed on the subject such as (Harmon, Zigman, & Drezner, 2015; Exeter, et al., 2014 and Brosnan, et al., 2014). The outcome evaluation was a simple statistical analysis of the accuracy in interpretation of ECGs from the pre and post education. The main expected outcome was the increase in the accuracy of correctly reading ECGs as normal or abnormal after the education program was implemented, along with a reduced false positive rate.

Table 1. Cost Breakdown

Item	**Cost**
Physical Materials	
Copier paper 3 reams	$17.00
Manila envelopes	$13.00
Copying/printing of project handouts/questionnaires	$250.00
Computer Information Systems	
Laptop equipped with Microsoft Excel software (not needed for purchasing for project)	$1,700.00 [not included in total cost of project, owned by student investigator]
Copier printer (not purchased)	$149.00 [not included in total cost of project, owned by student investigator]
Software license for IBM SPSS statistical software	$119.00 [student rate supported by UMASS OIT]
Personnel	

DNP student as project investigator	
Transportation/Travel	
Travel/commuting expenses to/from practice setting (gas and parking fees)	$800.00 [not included in budget as student investigator will be on site for other educational activities with personal benefit]
Project Space for Program Implementation	
Meetings spaces (located within practice setting)	No cost (available free of charge within practice setting, i.e. provider offices/exam rooms)
Total Cost/Expenses	
Total Estimated Cost Services previously acquired student investigator or provided gratis by site **Total Actual Costs**	$3048.00 $2649.00 **$399.00 (final cost of project implementation)**

The DNP student absorbed all costs and associated activities for the project. The implementation of this project was in conjunction with the students course work and did not incur other time expenses in relation to the implementation and analysis of the project. UHS did not lose any revenue from patient care, as each participant volunteered their time to complete the project requirements on their own non- work time. The participants agreed to participate based on the perceived need for the merits of the projects potential to improve patient care. As a university-based enterprise, this project aligns with the goal of furthering education and creating better understanding of best practices.

There were no risks identified to the participation in the project and there were no personally identifiable data collected. All pre and post interventional materials were coded for pairing. Anonymity was maintained by using coded manila envelopes to deliver and receive program materials from participants as well as IRB waiver of signed consent. Participants received informed consent materials in their packages but were not required to sign. A central drop off and pick up location was used to ensure the anonymity of the participants.

Evaluation

A pre and post intervention study was conducted during the fall of 2015 and winter of 2016 after obtaining approval from the appropriate Institutional Review Board. Study participants included physicians and nurse practitioners practicing in areas including adult and pediatric primary, sports medicine, urgent care and women's health recruited from a university based health services center of a research university in western Massachusetts.

In the pre-intervention period participants were asked to interpret a sample of 40 ECGs and classify them as normal or abnormal. The ECGs used in this study were provided by the Massachusetts General Hospital division of Sports Performance. The composition of the 40 ECGs included 26 normal and 14 abnormal ECGs that were selected by a board certified cardiologist. No personally identifying information was included on the ECGs only the age and race of the individual was provided.

The order of the ECGs was determined by a random order generator mixing the 26 normal and 14 abnormal into a group of 40 ECGs to be interpreted. Two such randomizations were conducted one for the pre-intervention group of ECGs and one for the post intervention group of ECGs. The participants were instructed to use their current understanding of ECG interpretation in the analysis of the ECGs in the pre intervention group. Then they were instructed to use the information gained in the BJSM course to reinterpret the ECGs.

As in previous studies by Exeter et al., (2014) and Drezner et al., (2012) the "normal" ECGs used in this study were those consistent with expected, training-related changes seen in athletes including sinus bradycardia, sinus arrhythmia, early repolarization and increases in QRS voltage. The abnormal ECGs included ECGs indicative of pathology, including hypertrophic cardiomyopathy (HCM), Wolff-Parkinson White syndrome, arrythmogenic right ventricular cardiomyopathy (AVRC), left ventricular non-compaction and Brugada syndrome.

The intervention in this study was an online course from the British Journal of Sports Medicine titled “ECG interpretation in athletes”. Following completion of the course the study participants were asked to reinterpreted the same set of ECGs but presented in a different order. The outcome measures included: false positive rates, sensitivity and specificity.

Statistical analysis

The statistical analysis was performed using IBM SPSS version 23 statistical software. The continuous variables were tested for normality of distribution and found to be moderately skewed. A Log10 transformation was performed and these results were evaluated with descriptive statistics and a paired t test. Significance was assumed at $p < 0.05$. All variables are reported as mean +/-SD and 95% CI.

Results

Thirteen of the 18 clinicians recruited for the study returned the program materials by the due date for a total participation rate of 72%. The participants were comprised of eight physicians and five nurse practitioners with a mean of 19 years of experience as illustrated in Table I.

Table I. How long in practice

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	6-10 years	1	7.7	7.7	7.7
	11-15 years	4	30.8	30.8	38.5
	16-20 years	4	30.8	30.8	69.2
	> 20 years	4	30.8	30.8	100.0
	Total	13	100.0	100.0	

None of the providers had any specialized training in the interpretation of ECG in athletes. The providers had an overall false positive rate of 21% +/- 14%, a sensitivity of 73% +/- 11% and a specificity of 78% +/- 14% during the pre-intervention interpretation of the ECG as illustrated in Table II.

Table II. Statistics Pre and Post Intervention on Detecting False Positives

		How long in practice	Professional Credentials	Pre class False Positive	Post class False Positive	Pre Class Spec	Post Class Spec
N	Valid	13	13	13	13	13	13
	Missing	0	0	0	0	0	0
Mean		3.85	1.38	.2090	.1304	.7827	.8695
Std. Error of Mean		.274	.140	.03759	.02518	.03932	.02518
Std. Deviation		.987	.506	.13554	.09079	.14178	.09078
Minimum		2	1	.08	.04	.42	.62
Maximum		5	2	.58	.38	.92	.96

After completing the ECG course, the there was a significant reduction in false positive rates and increased sensitivity and specificity. There were no significant differences between the physician and nurse practitioner groups (p=0.38).

Table III. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre class False Positive	.2090	13	.13554	.03759
	Post class False Positive	.1304	13	.09079	.02518
Pair 2	Pre Class Sens	.7357	13	.11087	.03075
	Post Class Sens	.8339	13	.07492	.02078
Pair 3	Pre Class Spec	.7827	13	.14178	.03932
	Post Class Spec	.8695	13	.09078	.02518

The mean scores for false positives, sensitivity and specificity during the pre and post intervention ECG interpretations were paired and entered into a paired samples t-test to assess significance of the scores pre and post intervention. Table IV shows the intervention was able to show significant improvement providers accuracy in ECG interpretation.

Table IV. Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre class False Positive - Post class False Positive	.0785	.07115	.01973	.03554	.12153	3.980	12	.002
Pair 2	Pre Class Sens - Post Class Sens	-.0982	.10297	.02856	-.16048	-.03603	-3.441	12	.005
Pair 3	Pre Class Spec - Post Class Spec	-.0868	.07705	.02137	-.13338	-.04026	-4.063	12	.002

The study sample consisted of both physicians and nurse practitioners. This allowed a comparison of accuracy between the groups. As table V illustrates the NP group had higher baseline false positives and lower specificity compared to the MD group (27% v 17% and 70% v 83%) in the pre intervention interpretations. Interestingly the results for sensitivity were consistent between groups. However, there were no significant differences found between the groups (p=0.38) as illustrated below in Table V.

Table V. Summary of Results of Provider training on ECG Interpretation

Provider Type	False + Pre/Post	Sensitivity Pre/Post	Specificity Pre/Post
NP (N=5)	27%/19% (p=0.071)	74%/83% (p=0.640)	70%/80% (p=0.093)
MD (N=8)	17%/9% (p=0.003)	73%/83% (p=0.166)	83%/91% (p=0.003)
Total (N=13)	**21%/13% (p=0.013)**	**73%/83% (p=0.005)**	**78%/86% (p=0.002)**

Discussion

This study demonstrated the effectiveness of an educational program in improving accuracy of ECG interpretation in athletes by primary care clinicians. If we hope to increase the numbers of primary care providers to participate in screening programs we need to look at more than just as six-hour online course. The American Association of Nurse Practitioners (AANP) 2015 fact sheet shows that FNPs make up 54.5% of all NP while ACNP make up only 7.5% of all NP. It makes sense that the largest group with the greatest exposure to primary care would have some didactic and practical experience in ECG interpretation.

Does this mean a specific course in ECG interpretation should be included in NP curricula or that more exposure to ECG spread out in various course be attempted? Pre-participation screening not withstanding competency in ECG analysis should be at least a minimum competency for practice and these results show that in this group of NP some more basic interpretation skills would be an asset. Answers to these questions are beyond the scope of this study but do need to be asked.

This study much like Drezner et al. (2012) and Exeter et al. (2014) was designed to assess of application of modern ECG interpretation criteria reduced false positive rates in the analysis of ECGs in athletes. The results while each study showed significant increases in accuracy the current study approached the method differently. In both Drezner et al. (2012) and Exeter et al (2014) the participants were given an interpretation tool to use during the examination of the ECGs in question. This study while grounded in adult learning theory asked providers to take a didactic online course in the ECG changes of the athletes' heart.

This study does have limitations. Though participants reviewed a substantial number of ECGs 40 in total the small pool of both MD and NP participants make generalizing results to other groups difficult. This particular study was not a randomized control study and as such cannot say for certain that the intervention would hold the same level of significance across groups. This was a convenience sample of providers who volunteered and as such there may have been a degree of selection bias in the participants who had an interest in ECG interpretation. All providers practiced in the same university based health center and as such may have similar backgrounds and practice style.

In order for any screening process with ECG to be practical a larger pool of qualified providers is required to administer and interpret the ECGs. One potential way of accomplishing this goal will be to enlist primary care physicians, nurse practitioners (NP) and physician assistants (PA) to be part of the team assembled to provide screening services. Pickham, Chan, & Carey (2015), suggest a possible approach of using primary care NPs and PAs as one method to increase the numbers of qualified providers. They further suggest that the educational course offered by the BJSM potentially as one method of increasing education for these providers. This study is the first of its kind to assess the effectiveness of the BJSM course in increasing the sensitivity of ECG and lowering false positive rate in ECG screening of athletes by non-specialist primary care providers including NPs.

Conclusion

Sudden cardiac death (SCD) is a leading cause of mortality in athletes during practice and competition. In these athletes the most common causes of SCD are undiagnosed cardiac abnormalities with hypertrophic cardiomyopathy (HCM) being the most common cause in almost 50% of the cases (Maron, Epstein, & Roberts, 1986; Harmon, et al., 2015). This study demonstrated the effectiveness of an education intervention in increasing the accuracy of ECG interpretation by primary care providers. The study limitations, including small sample size and use of a convenience sample at a single site limit the generalizability of the results. Further research is clearly needed that address these limitations, e.g., a larger study with participants from a variety of practice settings. The result of these larger studies may ultimately result in a body of knowledge that makes the long-term goal of increased screening a standard of care for student athletes.

This study has served as a pilot and will be the basis for a larger multiyear study. This new study will recruit participants from multiple centers and backgrounds. Then hopefully we can show that online education is a practical method to increase the number of primary care providers available to perform PPS with ECGs. A knowledge gap exists in the numbers of the true prevalence of ECG predisposing to SCD in athletes. This is due to non-uniform reporting methods and a paucity of longitudinal studies. A screening program will be undertaken at a large northeastern research university over the next several years which will endeavor to help shed light on the true prevalence of ECG abnormalities predisposing to SCD in athletes.

References

American College of Cardiology. (2014). 2013 ACC/AHA Guideline on the Assesment of Cardiovascular Risk. Washington, D.C., USA. Retrieved February 6, 2015

American Association of Nurse Practitioners - NP Fact Shee*t*. (2016). *Aanp.org*.

Asif, I., & Drezner, J. (2014). Sudden cardiac death and preparticipation screening: The debate continues- In support of electrocardiogram inclusive preparticipation screening. *Progress in Cardiovasular Disease, 54*, pp. 445-450. doi:10.1016.j.pcad.2012.01.001

Asif, I., Johnson, S., Schmieg, J., Smith, T., Rao, A., Harmon, K., . . . Drezner, J. (2014). The psychological impact of cardiovascular screening: the athlete's perspective. *British Journal of Sports Medicine, 48*, pp. 1162-1166. doi:10.1136/bjsports-2014-093500

Brosnan, M., LaGerche, A., Kalman, J., Lo, W., Fallon, K., MacIssac, A., & Prior, D. (2014). The Seattle Criteria increase the specificity of preparticipation ECG screening among elite athletes. *British Journal of Sports Medicine, 48*, 1144-1150.

Corrado, D., Pelliccia, A., Bjornstad, H., Vanhees, L., Biffi, A., Borjesson, M., . . . Delise, P. (2005). Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: a proposal for a common European protocol. *European Heart Journal, 26*, pp. 516-524. doi:10.1093/eurheartj/ehi108

Drezner, J. (2012). Standardised criteria for ECG interpretation in athletes: a practical tool. *British Journal of Sports Medicine, 46*(Supplement 1). doi:10.1136/bjsports-2012-091703

Drezner, J., & Corrado, D. (2011). Is there evidence for recommending electrocardiogram as part of the pre-participation examination? *Clinical Journal of Sports Medicine, 21*, pp. 18-24. Retrieved 10 22, 2014

Drezner, J., Ackerman, M., Anderson, J., Ashley, E., Asplund, C., Baggish, A., . . . Owens, D. (2013). Electrocardiographic interpretation in athletes: the 'Seattle Criteria'. *British Journal of Sports Medicine, 47*, pp. 122-124. doi:10.1136/bjsports-2012-092067

Drezner, J., Asif, I., Owens, D., Prutkin, J., Salerno, J., Fean, R., . . . Harmon, K. (2012). Accuracy of ECG interpretation in competive athletes: the impact of using standardised ECG criteria. *British Journal of Sports Medicine, 46*, pp. 335-340. doi:10.1136/bjsports-2012-090612

Dunn, T. P., Pickham, D., Aggarwal, S., Saini, D., Kumar, N., Wheeler, M. T., . . . Froelicher, V. F. (2015). Limitations of Current AHA Guidelines and Proposal of New Guidelines for Preparticipation Examination of Athletes. *Clinical Journal of Sports Medicine, 0*, 1-6.

Estes III, N. M., & Link, M. (2012). Preparticipation athletic screening including an electrocardiogram: An unproven strategy for prevention of sudden cardiac death in the athlete. *Progress in Cardiovascular Diseases, 54*, pp. 451-454.

Exeter, D. J., Elley, C. R., Fulcher, M. L., Lee, A. C., Drezner, J. A., & Asif, I. M. (2014). Standardised critera improve accuracy of ECG interpretation in competitive athletes: a randomised controlled trial. *British Journal of Sports Medicine, 48*, 1167-1171.

Fudge, J., Harmon, K., Owens, D., Prutkin, J., Salerno, J., Asif, I., . . . Drezner, J. (2014). Cardiovascular screening in adolescents and young adults: a prospective study comparing the Pre-participation physical evaluation monograph 4th edition and ECG. *British Journal of Sports Medicine, 48*, pp. 1172-1178. doi:10.1136/bjsm-2014-093840

Harmon, K. G., Zigman, M., & Drezner, J. A. (2015). The effectiveness of screening history, physical exam, and ECG to detect potentially lethal cardiac disorders in athletes: A systemic review / meta analysis. *Journal of Electrocardiology, 48*, 329-338.

Harmon, K., Asif, I., Maleszewski, J., Owens, D., Prutkin, J., Salerno, J., . . . Drezner, J. (2015). Incidence, Cause, and Comparative Frequency of Sudden Cardiac Death in National Collegiate Athletic Association Athgletes: A Decade of Review. *Circulation, 132*, 10-19.

Knowles, M. S. (1998). *The adult learner* (5th ed.). Huston, Texas: Gulf Publishing.

Lindeman, E. C. (1926). *The meaning of adult education* (5th ed.). New York.

Link, M., & Estes III, N. M. (2012). Sudden cardiac death in the athlete: Bridging the gaps between evidence, policy and practice. *Circulation*, pp. 2511-2516.

Maron, B. J., Epstein, S. E., & Roberts, W. C. (1986). Causes of Sudden Death in Competitive Athletes. *Journal of the American College of Cardiology, 7*(1), 204-14.

Maron, B. j., Friedman, R. A., Kligfield, P., Levine, B. D., Viskin, S., Chaitman, B. R., . . . VanHare, G. F. (2014). Assessment of the 12-lead electrocardiogram as a screening test for detection of cardiovascular disease in healthy general populations of young people (12-25 years of age). *Journal of the American College of Cardiology, 64*(14), 1479-1514.

Maron, B., Thompson, P., Ackerman, M., Balady, G., Berger, S., Cohen, D., . . . Puffer, J. (2007). Recommendations and considerations related to preparticipation screening for cardiovascular abnormalities in competitive athletes. *Circulation, 115*, pp. 1643-1655.

Morse, E., & Funk, M. (2012). Preparticipation screening and prevention of sudden cardiac death in athletes: Implications for primary care. *Journal of the American Academy of Nurse Practitioners, 24*, pp. 63-69. doi:10.1111/j.1745-7599.2011.00694.x

Pickham, D., Chan, G., & Carey, M. (2015). Pre-participation screening for athletes and role of advanced practice providers. *Journal of Electrocardiology, 48*, 339-344.

Speroff, T., & O'Connor, G. T. (2004). Study design for PDSA quality improvement research. *Quality Management in Health Care, 17*(1), 17-32.

Wilson, M. G., Basavarajaiah, S., Whyte, G. P., Cox, S., Loosemore, M., & Sharma, S. (2008). Efficacy of personal symptom andfamily history questionnaires when screening for inherited cardiac pathologies: the role of electrocardiography. *British Journal of Sports Medicine, 42*, 207-11.

Womack, J. (2011). Sudden Cardiac Death in Athletes: Is Universal ECG Screening Plausible. *Asian Journal of Sports Medicine, 2*(2), 117-119.