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Don't Just Check the Box: Check Your Athlete's Heart: Adding a 12-lead ECG to Pre-Participation Screening to Identify High Risk of Sudden Cardiac Arrest in Male High School Athletes

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Abstract

PURPOSE: Sudden cardiac arrest (SCA) continues to be the leading cause of death in male high school athletes participating in competitive sports. There is gap in the current preventative screening practice of history and physical alone. The purpose of this project is to evaluate adding a 12-lead electrocardiogram (ECG) to pre-participation screening captures cardiac abnormalities that identify male athletes at a higher risk for developing SCA. METHODS: A descriptive secondary analysis design to determine the incidence of cardiac abnormalities detected with the addition of a 12-lead ECG during pre-participation screenings (annual sports physical) of high school-aged male athletes. The study was conducted in two parts. Part 1 included direct experiential learning observation at four prevention-screening sessions between the months of July and August 2020. Part 2 was a retrospective secondary analysis of data collected by the MCORE Foundation during previous preventative screenings to find correlation and feasibility of adding a 12-lead ECG and cardiac questionnaire to pre-participation screenings. RESULTS: The study identified a significant correlation between ECG findings and the pediatric cardiologist's interpretations. CONCLUSION: Adding a 12-lead ECG showed significant correlation with pediatric cardiologist recommendations for treatment and evaluation.

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TABLE OF CONTENTS

Don't Just Check the Box, Check Your Athlete's Heart: Adding a 12-lead ECG to Pre-participation Screening to Identify High Risk of SCA in Male High School Athletes

Introduction

Sudden cardiac arrest (SCA) is a leading cause of death in children and young adults (Sudden Cardiac Arrest Foundation, 2014). Sudden cardiac arrest usually causes death if it is not treated within minutes (National Heart, Lung, and Brain Institute, 2016). A combination of physical exercise and underlying cardiovascular disorders can be potentially lethal. As an athlete participates in physical activity, there are changes in blood pressure. These blood pressure changes increase blood flow and cardiac demand. If an athlete has an underlying and undiagnosed cardiac disorder, that increase in cardiac demand can cause a short-term trigger of arrhythmias. Long-term these changes in pressure and cardiac demand can cause maladaptive remodeling with ventricular enlargement, increased myocardial fibrosis, and artery wall stiffening (Atteya, et. al, 2017). Research has shown that competitive athletes are at a higher risk for sudden cardiac arrest (Gilchrist, et. al, 2012). Within that group, specifically, male athletes of any ethnicity that play football, basketball, or soccer are at the highest risk comprising 75% of all SCA (Drezner, et. al, 2016). According to Kentucky legislation KRS 156.070, "every local board of education shall require an annual medical examination performed and signed by a physician, physician assistant, advanced practice registered nurse, or chiropractor, if performed within the professional's scope of practice, for each student seeking eligibility to participate in any school athletic activity or sport (Kentucky General Assembly, 2020). The current legislation statute does not specify any individual components of the medical examination for the annual exam. Because of the high incidence of SCA among high school athletes, there is a movement from healthcare agencies, providers and community members to require a 12-lead ECG for pre-participation screening for high school athletes to potentially identify undetected and, in many cases without symptoms, cardiac abnormalities that could lead to SCA. A study conducted by Maron, et. al, shows that athletes with a family history of cardiovascular disorders (cardiomyopathy, Long QT syndrome, and coronary artery disease) are at greater risk for SCA (Maron, et. al, 2016). The National Heart, Lung, and Blood Institute issued a report in 2015 stating that SCA in youth athletes was a "critical public health issue" (Ackerman, et. al, 2016). These unfortunate events occur even with the recent addition of the American Heart Association 14-point questionnaire pre-participation screening tool (Appendix A) during annual sports physicals. When a 12-lead ECG is added to the annual physical examination the AHA screening questionnaire is used and physical examination are performed, 1 in 100 youth screened are able to be identified as 'at risk for a sudden cardiac arrest event', (Hainline, et. al, 2016). If student athletes are screened with only a medical history and physical exam, 96% of youth at risk for SCD may be missed (Drezner, et. al, 2016).

Despite the wealth of evidence supporting the addition of a 12-lead ECG to pre-participation screening, there is still a gap in practice due to a lack of mandatory and systematic screening during the annual physical examination for sports. The argument and resistance for recommending, not requiring, the testing is inconsistency in, reading/results, associated costs, and negative effects on the athletes' self-esteem with a false-positive result (Drezner, 2015). There is an opportunity to fill these gaps by developing a cardiovascular screening program for young competitive athletes. Board-certified cardiologists or specialty trained advanced practice nurses can evaluate the results from the screenings to reduce reading errors. There is no study to date that has demonstrated that screening by history and physical alone is effective in detecting athletes at risk or in preventing SCD (Drezner, et. al, 2016). In an effort to increase awareness for sudden cardiac arrest, these expanded screenings should also be made available to all such athletes in every public and private high school in Fayette County, KY, and every county in the state of Kentucky.

Synthesis of the Evidence

Knowledge of SCA is key for the prevention of potentially lethal cardiac conditions including sudden cardiac death. Sudden cardiac arrest is usually caused by an asymptomatic heart disease like coronary artery disease, long QT syndrome and hypertrophic cardiomyopathy. Electrocardiogram tests are an early step in a process to establish a definitive pre-existing condition that could lead to SCA.

With the addition of a 12-lead ECG, research shows an 89% decrease in incidence (Corrado…et al, 2006) and an increase in the sensitivity of identifying individuals at risk for SCA (Corrado 2006; Dutchem 2003). Investigators from several studies mentioned above (Corrado, et. al, 2006), recognize that athletes represent a special sub-set of the general population who are at a higher risk for SCA. That recognition led to a national mandated and funded systematic screening that was associated with a decline in deaths from SCA (Corrado, et. al, 2006) in Europe. The International Olympic Committee has also mandated medical pre-participation screening to include a baseline ECG for all competing athletes (Bergeron, et. al, 2015). Research also shows an increased incidence of SCA in Division I college athletes prompting the National College Athletic Association (NCAA) to require 12-lead ECG testing on all athletes (Drezner, et al, 2017).

The American College of Cardiology only recommends, rather than mandates, the AHA 14-point questionnaire, and ECG (with a physician present), and a physical examination. A targeted personal family history and physical examination plus a 12-lead ECG with interpretation are mandated in Italy, Japan, and Israel (American College of Cardiology, 2017).

Progress cannot be made without proof of success and interest from legislators, school administration, athletic associations, parents, and athletes alike. Showing the inconsistencies of the current standard of screening and the results that have been produced from previous institutions and studies will aid in bolstering the public opinion for change. The need for a full evaluation of the pre-participation screening process for high school athletes in competitive sports is of great importance. A change in the screening should include the addition of an ECG test to the pre-participation screening requirements.

Purpose Statement

The purpose of this project is to identify a population for SCA by adding an additional component to the pre-participation screening process to identify cardiac abnormalities. The specific aims were to:

1. Identify student competitive athletes that may be at an increased risk for SCA that would have gone undetected without the aid of a cardiac history, and a 12-lead ECG
2. Determine and compare local cardiac abnormalities incident rates in a cohort of student athletes screened in a Tri-State area (Indiana, Kentucky and Ohio) to the published national incident rate.

Theoretical Framework

The theoretical framework used for this project is the Lewin's Change Theory (1951): 1) Unfreezing, 2) Moving, and 3) Refreezing. Lewin's Change Theory operates under the assumption that people or groups of people work under restrained forces or obstacles with a mentality of change is bad. Conversely, the theory also works under the impression that people can work through driving forces that are positive or change agents. Unfreezing can be accomplished by examining the research showing the importance and success of changing the pre-participation screening process to include the addition of a baseline ECG and creating an interest in being part of the driving force for the change. Educating and challenging the status quo can bring the issue to the forefront. Moving is “taking action” by gaining interest and obtaining key stakeholders to help in implementing local pilot cardiovascular screening programs and by getting those in the community involved. This pilot screening shows the benefit of the change by offering alternatives to current practice. Refreezing is establishing a new way of screening athletes while continuing to monitor key performance indicators. Results of standardized prevention screenings can be taken to key stakeholders to gain momentum for legislation to have the pre-participation screening process changed and mandated for all schools in the state of Kentucky.

Cost-effectiveness Analysis

The inclusion of a 12-lead ECG in pre-participation screening of young athletes is controversial in current practice because of cost-effectiveness. Screening young athletes with a 12-lead ECG plus a cardiovascular-focused history can be cost-effective. Halkin, et al. estimate there are close to 10 million athletes in the United States (high school, NCAA, NAIA, and professional). If a 12-lead ECG is used for pre-participation screening, 10,000 will have a true positive ECG. The cost per athlete detected with cardiac disease is $300,000. It would cost $50 billion to create a program of this magnitude with an estimated

4800 lives saved. Analysis estimates that adding an ECG to the existing screening requirements saves 2.06 life-years/1000 athletes screened at a cost of $42,000/life-year saved compared to history and physical alone (Lavie & Harmon, 2016). Comparison of ECG plus history and physical examination to cardiovascular-focused history and physical examination alone saves 2.1 life-years per 1000 athletes screened at an incremental cost of $88 per athlete. The incremental cost-effectiveness ratio of adding ECG plus history and physical examination versus history and physical examination alone was $42 900 per life-year saved/$61 600 per Quality Adjusted Life Year (QALY) saved (Wheeler, et. al, 2010)

Methods

Design

This study used a descriptive secondary analysis design to determine the incidence of cardiac abnormalities detected with the addition of a 12-lead ECG during pre-participation screenings (annual sports physical) of high school-aged male athletes. The study was conducted in two parts. Part 1 included direct experiential learning observation at four prevention-screening sessions between the months of July and August 2020. Part 2 was a retrospective secondary analysis of data collected by the MCORE Foundation during previous preventative screenings to find correlation and feasibility of adding a 12-lead ECG and cardiac questionnaire to pre-participation screenings. Outcome variables included survey questionnaires, sport(s) participated, ECG abnormalities, and ECG interpretations and recommendations. A partnership was formed with MCORE Foundation, an Ohio-based 501(c) 3 organization with a mission to increase awareness of sudden cardiac death and provide dependable, low-cost screening to every student athlete possible, in the hopes that achieving these objectives will save lives (MCORE Foundation, 2020).

Setting

Part 1 of the study was conducted in three separate Kentucky high schools: School A (St. Henry), School B (Covington Catholic), and School C (Beechwood). Every site was consistent in screening materials provided by MCORE: a 14-element cardiac questionnaire, physical assessment, electrocardiography, and echocardiography (if recommended). Part 2 was conducted in high schools in Kentucky, Ohio, and Indiana. The results were comprised of 200 randomized, de-identified preventative 12-lead ECG and cardiac questionnaire screenings performed on de-identified male athletes between the ages of 12-17.

Detailed description of the setting(s)

Agency	Enrollment	Descriptive
School A	Total Students: 543	Private, Catholic
	43% - Female 57% - Male	Largest Catholic college-prep co-ed high school
	Student/Teacher Ratio: 13:1	Male Sports Offered: 10
	97.1 %White 0.2% African American 1.1 % Hispanic 1.3 % Other	Nationally recognized Blue Ribbon school

Agency	Enrollment	Descriptive
School B	Total Students: 603	Private, Roman Catholic
	0% - Female 100% - Male	Project Lead the Way Engineering program
	Student/Teacher Ratio: 14:1	Male Sports Offered: 13
	95.4% White 0.2% African American 2.2% Hispanic 2.6% Other	Blue Ribbon School National Council of Private Schools

Agency	Enrollment	Descriptive
School C	Total Students: 647	Public, Independent 7-12
	49.1% - Female 50.9% - Male	Top 20% of Public School in Kentucky
	Student/Teacher Ratio: 17:1	Male Sports Offered: 15
	87.4% White 0.7% African American 6.5% Hispanic 6.5% Other	Blue Ribbon School Edge Program

Sample

The primary investigator had direct observation of the MCORE Foundation's methods and techniques used in collecting the data during the preventative screenings at the participating high schools for part 1 of the study. For Part 2 of the study, a randomization schema was conducted with 1000 preventative screenings, 200 of which were selected in a computerized randomization for secondary data analysis. Pediatric cardiologists from Cincinnati Children's Hospital read all of the ECGs obtained from athlete participants. Inclusion criteria for participants were 1) male, 2) between the ages of 12-17, and 3) played a competitive sport. Exclusion criteria included students that were 1) female, 2) younger than 12 years and older than 17 years of age at the time of the screening, and 3) did not play in pre-determined competitive sport(s).

Data Collection

The Not Human Research (NHR) determination form was completed and submitted to the Office of Research Integrity (ORI) at the University of Kentucky. Approval was obtained prior to secondary data analyses. For Part 2 of the study, MCORE provided the primary investigator with the de-identified athlete information for those participants that met the inclusion criteria.

Data Analysis

The computer software Statistical Package for the Social Sciences (SPSS) program, Version 26 for statistical analysis was completed. Descriptive statistics including frequency distribution and cross tabulation described the study population and baseline characteristics. The chi-square test of correlation and the Pearson correlation test examined the relationships between sports, athlete history, family history and the ECG interpretations. Logistic regression examined the relationship between the dependent and independent variables.

Results

Analysis of data from 200 athletes was completed. Missing and duplicate data were extracted from the dataset. The final sample size was 188 athletes. There were nine competitive sports represented within the sample population: baseball (30/15.9), basketball (63/33.5), football (56/29.8), hockey (6/3.1), lacrosse (22/11.7), soccer (33/17.6), swim (including diving) (14/7.4), track (including cross-country) (44/23.4), and wrestling (12/6.4) (Table 1).

Abnormal ECG interpretations were stratified using the variables abnormal finding with no additional testing required, abnormal findings with additional testing required, abnormal findings with further evaluation required and significant finding with an immediate stop in participation required until further examination. Of the 188 study participants, 178 had abnormal ECG readings. Of those 178 abnormalities, 45 (23.9%) required further evaluation with two (4.4%) readings requiring an immediate stop in participation. Both baseball and basketball had a participant that had significant findings requiring the athlete to stop participation immediately. The top 5 sports that had abnormal findings requiring further evaluation were 1) hockey (33.3%), 2) soccer (30.3%), 3) football (26.8%), baseball (26.7%), and 5) basketball(23.8%) (Figure 1). There was a significant correlation between the ECG findings and the pediatric cardiologist's interpretations. This significant correlation supports the study's purpose to providing additional information useful in identifying cardiac abnormalities.

Specific ECG Abnormalities

The specific ECG abnormalities were determined by axis deviation, conduction, rhythm, structural, ST segment, and hypertrophy. There were 27 athletes with axis deviations, 11 of those were left axis and 16 had right axis deviations. There were 25 athletes with conduction abnormalities, 16 were classified as intraventricular conduction delays and 9 right bundle branch blocks. There were 11 athletes with general rhythm abnormalities, 1 with a first-degree block, 1 with premature atrial contractions, and 9 with premature ventricular contractions. There were 58 athletes with ST segment changes. Hypertrophic abnormalities were found in 20 athletes, 1 with left ventricular hypertrophic changes, and 1 with right ventricular hypertrophic changes, 18 with left ventricular thickening or enlargement and 4 with right ventricular thickening or enlargement. The cardiologists read only 10 of the 188 ECG readings as "normal". The data presented in this study show key similarities when compared with Maron, et. al (2012). Left ventricular thickening (hypertrophy) 9.5% to 8%; Normal 5.3% to 3%; Right ventricular thickening 2.1% to ARVC 4%; Rhythm abnormalities 5.9% to 3%. Dissimilarities were found in Hypertrophic cardiomyopathy 10.6% to 36% and ST segment changes 30.8% to Anomalous coronaries 17%. These dissimilarities could be contributed to differences in classification identification and amount of study participants (Figure 2).

Discussion

The purpose of this project was to identify a population at risk for SCA by adding an additional component to the pre-participation screening process to identify cardiac abnormalities. The study found a significant correlation between ECG findings and the pediatric cardiologist's interpretations. Of the two objectives evaluated in this study, there were some key findings discovered between the actual 12-lead electrocardiogram testing and the pediatric cardiologist interpretations/recommendations.

The specific aim to identify competitive athletes that may be at risk for SCA that would have gone undetected without the aid of a cardiac history and a 12-lead ECG was found statistically significant in the correlation between 12-lead ECG testing and cardiologist interpretations. These results compared to five studies previously published in peer-reviewed articles that showed statistical significance (p value = < 0.01) in using a 12-lead ECG in pre-participation screen in student athletes when compared to using history and physical alone (Drezner, 2015; Drezner, et. al, 2016; Demorest, 2013; & Harmon, et. al, 2015). Therefore, implementation of adding a 12-lead ECG test to pre-participation screening for high school athletes proves beneficial in detecting cardiac abnormalities compared to using history and physical alone.

The study showed some differences in comparison to the five previously mentioned studies. The Drezner, 2015 and Fudge, et. al, 2014 studies investigated SCA rates in high student athletes versus student non-athletes whereas this study investigated only male high school student athletes. The Drezner, et. al, 2016 study used male athletes but college-aged rather than high school-aged athletes. In the Demorest 2013 study, the focus was 12-lead ECG testing for all episodes of exercise-related syncope in athletes in America instead of all athletes participating in sports. Finally, the Harmon, et. al, 2015 study evaluated the sensitivity and specificity of a 12-lead ECG, history, and physical examination respectively and only considered potentially lethal cardiovascular conditions for screening detection.

The specific aim to determine and compare local cardiac abnormalities incident rates in a cohort of student athletes screened in the Tri-State area of Indiana, Kentucky and Ohio to other similar studies did not find statistical significance. However, key findings were discovered between male athletes participating in basketball, football, and soccer and SCD-related cardiac abnormalities. The Drezner, 2015 study found that male basketball, football and soccer athletes comprised 75% of all SCD despite traditional screening methods. This study found that of the male basketball, football and soccer athletes screened, 82.5% were found to have ECG abnormalities that warranted further evaluation. With that statistical support, if male athletes participating in certain sports have ECG abnormalities that warrant further evaluation, those same athletes (without the addition of an ECG) are at greater risk of an SCA occurrence.

Limitations

There were limitations found in the design of this study. Since data were extracted using secondary analysis, accuracy and standardization of testing is dependent on the documentation skills and technique of the sonographer technicians. The participant's parents primarily completed the questionnaires with little to no input provided by the athlete. Therefore, information could have been missed or overlooked. Furthermore, during the direct experiential learning observation part of the study, there were limited numbers of tests visualized. Therefore, accuracy was dependent on sonographer technician attestation that there was standardization with each test performed. The direct observation studies were also conducted on both male and female athletes. The mean number of participants for the five studies reviewed was 1747 compared to this study's 188. The small sample size, limited the identification of some associations (i.e. family history and ECG findings). This study was unable to capture ethnicity for participation characteristics and regression data analysis could not be completed.

Recommendations for Future Research

This study has shown several implications for future research. The study has shown that with a high prevalence of abnormal ECG readings in male athletes there is a need to identify cardiac abnormalities that could increase risk of SCA. More research needs to be completed in standardization of training and testing for male high school athletes. There is also a need for more robust studies analyzing the outcomes of adding a 12-lead ECG to pre-participation screening for high school male athletes. Identifying the cardiac abnormality is only one piece of the equation. Communities need increased awareness and understanding of the responsibility needed to respond to a cardiac emergency. There is a need for cardiac emergency response planning. A cardiac response plan should include an emergency response team, access and regular maintenance of automated electronic defibrillators (AED), practice drills and regular review of response planning.

Conclusion

The purpose of this study was to evaluate the feasibility of adding a 12-lead ECG to pre-participatory screening for male high school athletes to detect cardiac abnormalities that could increase the risk of SCA. Adding a 12-lead ECG showed significant correlation with pediatric cardiologist recommendations for treatment and evaluation. Male athletes participating in basketball, football and soccer showed a higher prevalence of cardiac abnormalities. More research is needed to analyze the outcomes of adding an ECG to pre-participation screenings. If an athlete is identified with a cardiac abnormality that puts him at an increased risk for sudden cardiac arrest, there will also be a need for emergency response planning and teaching in that athlete's community.

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Tables

Table 1. Participant Characteristics

Baseline Characteristics	Total N (%)	Abnl ECG No additional testing	Abnl ECG Additional testing needed	Abnl ECG additional eval needed	Significant findings STOP
Male Gender	N= 188	41 (21.8)	76 (40.4)	43 (22.9)	2 (1.1)
Sport					
Baseball	30 (15.9)	1(3.3)	15(50.0)	8(26.7)	1(3.3)
Basketball	63 (33.5)	17(27.0)	24(38.1)	15(23.8)	1(1.6)
Football	56 (29.8)	12(21.4)	20(35.7(	15(26.8)	-
Hockey	6 (3.1)	1(16.7)	1(16.7)	2(33.3)	-
Lacrosse	22 (11.7)	3(13.6)	8(36.3)	3(13.6)	-
Soccer	33 (17.6)	9(27.3)	13(39.4)	10(30.3)	-
Swim	14 (7.4)	3(21.4)	3(21.4)	3(21.4)	-
Track	44 (23.4)	12(27.2)	17(38.6)	10(22.7)	-
Wrestling	12 (6.4)	1(8.3)	9(75.0)	1(8.3)	-
Athlete Positive History N= 31					
Murmur	7(3.7)	-	3(42.9)	2(28.6)	1(14.3)
Chest Pain	6(3.2)	3(50.0)	2(33.3)	0(0)	-
Hypertension	8(4.3)	4(50.0)	-	4(50.0)	-
Seizure	2(1.1)	1(50)	1(50)	0(0)	-
Exercise-Induced Asthma	8(4.3)	1(12.5)	1(12.5)	2(50.0)	-
Family Positive History N= 23					
Cardiac	10(5.3)	2(20.0)	-	7(70.0)	-
Non-Cardiac	2(1.1)	-	-	2(100.0)	-
Fainting	3(3.2)	2(66.7)	-	1(33.3)	-
Seizures	3(3.2)	1(33.3)	-	2(66.7)	-
Hypertrophy	2(1.1)	-	2(100.0)	0(0)	-
Weakened	2(1.1)	1(50.0)	-	1(50.0)	-
Marfan	1(0.5)	-	1(100.0)	0(0)	-

ABNL=abnormal; ECG=electrocardiogram; EVAL=evaluation

Figures

Figure 1. ECG Abnormality/Sport

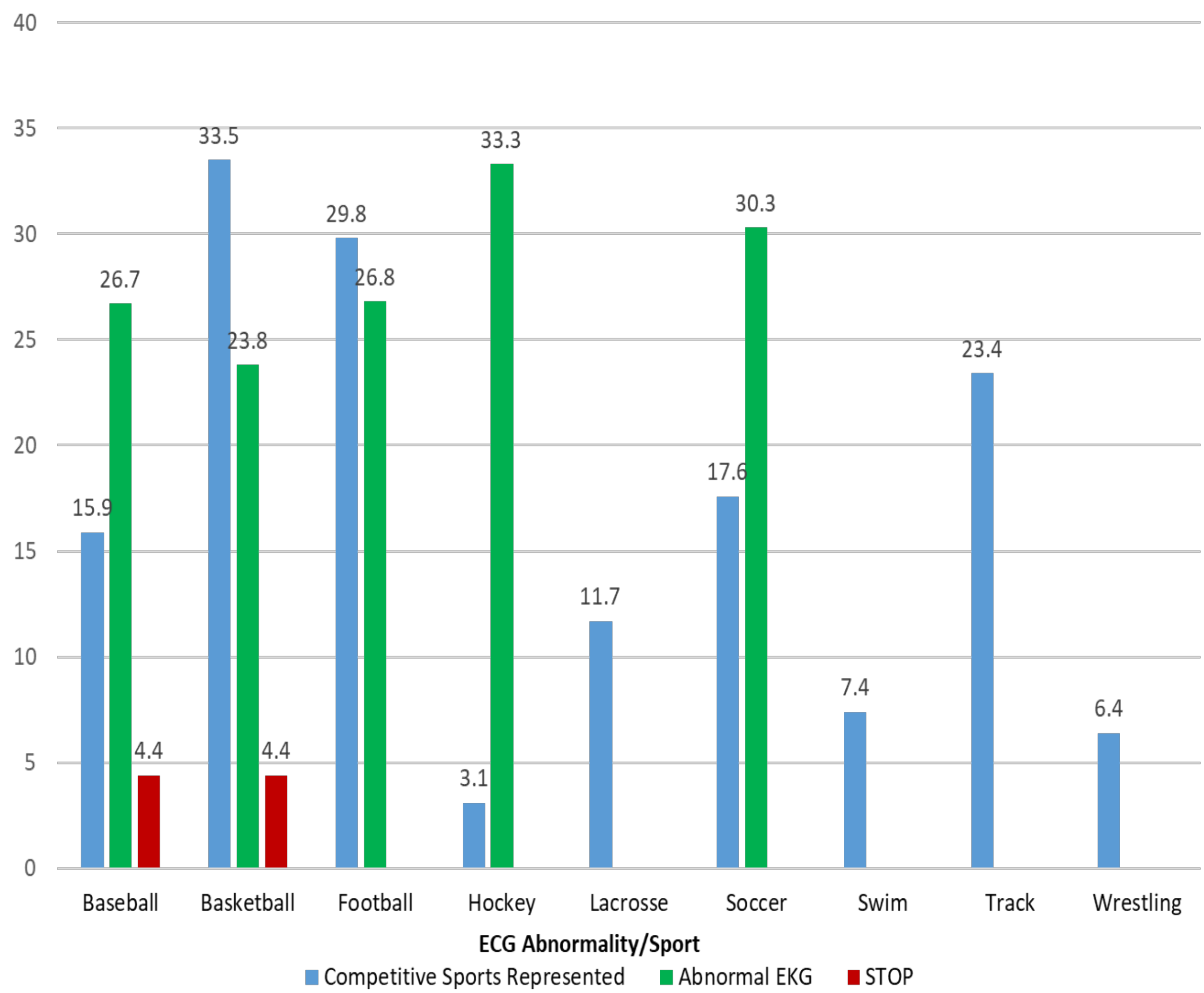
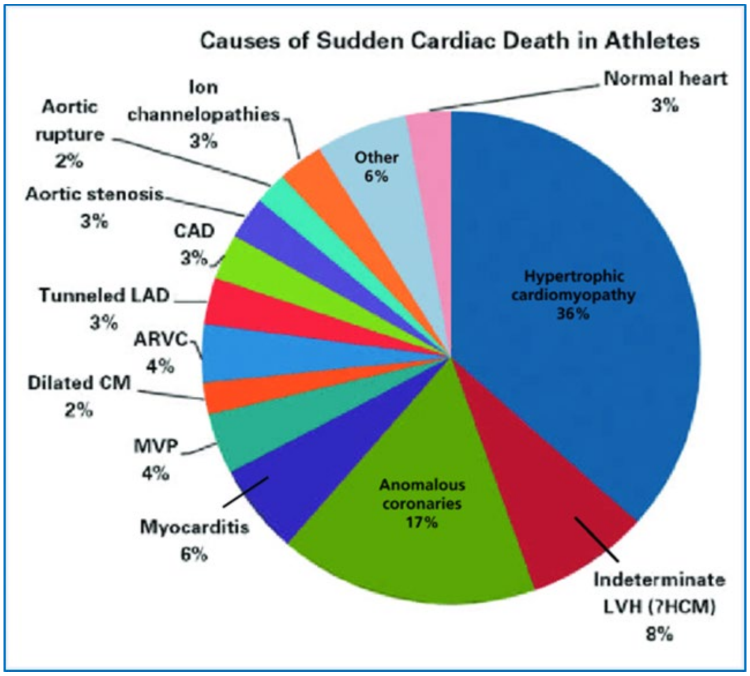
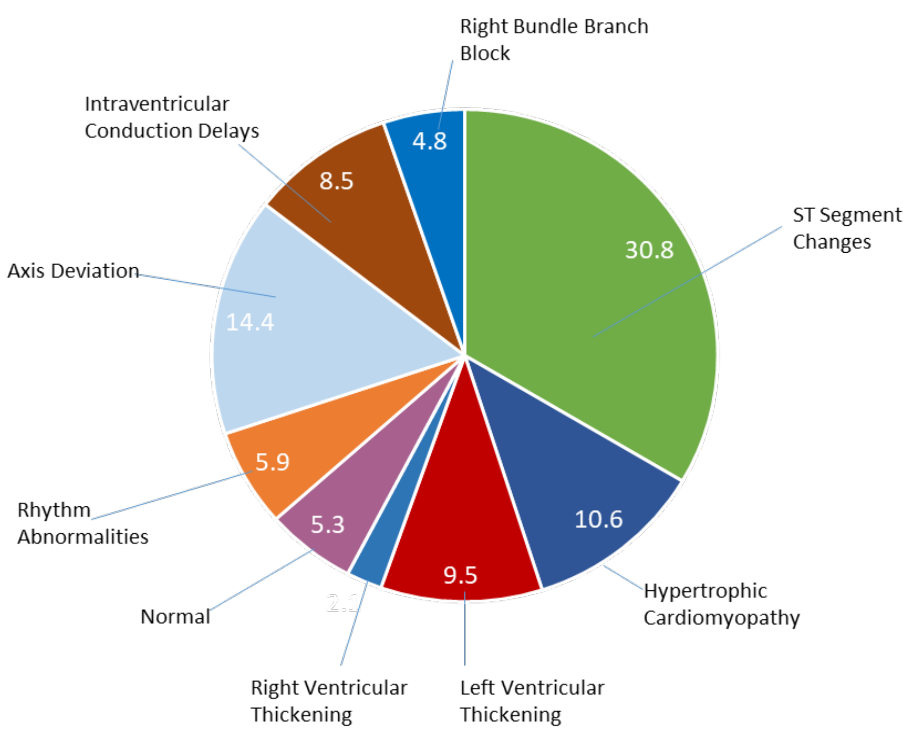


Figure 2. ECG Abnormality Comparisons

MARON COMPARISON STUDY



MCORE STUDY



Appendices

Appendix A. AHA 14-point Questionnaire

AHA Recommendations (10)*	PPE-4 (21)
Medical History†	
Personal History	**Heart Health Questions About You**
1. Chest pain/discomfort/tightness/pressure related to exertion	6. Have you ever had discomfort, pain, tightness, or pressure in your chest during exercise?
2. Unexplained syncope/near syncope‡	5. Have you ever passed out or nearly passed out *during* or *after* exercise?
3. Excessive and unexplained dyspnea/fatigue or palpitations, associated with exercise	12. Do you get more tired or short of breath more quickly than your friends during exercise? 10. Do you get lightheaded or feel more short of breath than expected during exercise? 7. Does your heart ever race or skip beats (irregular beats) during exercise?
4. Prior recognition of a heart murmur 5. Elevated systemic blood pressure	8. Has a doctor ever told you that you have any heart problems? If so, check all that apply: □ High blood pressure □ A heart murmur □ High cholesterol □ A heart infection □ Kawasaki disease Other: ___________
6. Prior restriction from sports	1. Has a doctor ever denied or restricted your participation in sports for any reason?
7. Prior testing for heart disease, ordered by a physician	9. Has a doctor ever ordered a test for your heart? (For example, ECG/EKG, echocardiogram) 11. **Have you ever had an unexplained seizure?**
Family History	**Heart Health Questions About Your Family**
8. Premature death (sudden and unexpected or otherwise) before 50 yrs of age attributable to heart disease in ≥1 relative	13. Has any family member or relative died of heart problems or had an unexpected death before age 50 yrs (including drowning, unexplained car accident, or sudden infant death syndrome)?
9. **Disability from heart disease in a close relative <50 yrs of age**	
10. Hypertrophic or dilated cardiomyopathy, long QT syndrome or other ion channelopathies, Marfan syndrome, or clinically significant arrhythmias; specific knowledge of genetic cardiac condition in family member	14. Does anyone in your family have hypertrophic cardiomyopathy, Marfan syndrome, arrhythmogenic right ventricular cardiomyopathy, long QT syndrome, short QT syndrome, Brugada syndrome, or catecholaminergic polymorphic ventricular tachycardia? 15. **Does anyone in your family have a heart problem, pacemaker, or implanted defibrillator?** 16. **Has anyone in your family had unexplained fainting, unexplained seizures, or near drowning?**