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Identifying Sudden Cardiac Arrest Risk in Adolescent Male Athletes

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ABSTRACT

International Journal of Exercise Science 17(2): 874-886, 2024. The purpose of the study was to determine the prevalence of sudden cardiac arrest (SCA) risk factors in high school (HS) athletes. Thirty-three male soccer players from a public HS in the southeastern United States (ages 14-17) self-reported survey data. Participants reported demographic, lifestyle, heart health, COVID-19 history, and symptoms indicative of SCA risk. An electrocardiogram (ECG) assessed heart rate (HR), rhythm, and electrical activity. Resting HR and blood pressure (BP) were measured with a BP monitor. The association between COVID-19 history, HR, and BP were calculated. Participants were divided into ECG groups (normal or abnormal). Independent t-tests assessed comparisons between groups to identify SCA risk. Over 50% of participants (n=17) reported experiencing shortness of breath (SOB) and 30% (n=10) reported chest pain. A history of chest pain was associated with abnormal ECGs ($p<0.04$). Thirteen (39.4%) participants reported a COVID-19 history. Of these, 5 presented with persisting symptoms, 2 with elevated HR, and 3 with elevated BP. Eleven (33.3%) participants had an abnormal ECG and of these eleven, 8 (72.7%) reported a positive COVID-19 history ($p<0.01$). The current American Heart Association suggested screening method is limited. An ECG should be used in preparticipation screenings (PPS) and return to participation (RTP) decisions for athletes with a COVID-19 history. Family cardiac history, chest pain during exercise, and an abnormal QRS interval should be used to identify SCA risk.

KEY WORDS: Fitness, cardiology, youth, soccer, exercise

INTRODUCTION

Sudden cardiac arrest (SCA) is the leading cause of non-traumatic death in adolescents participating in physical activity and sports despite preparticipation screening (PPS) (18). SCA is the sudden loss of heart function, breathing, and consciousness. In the United States, SCA accounts for approximately 110 adolescent athlete deaths per year, thus, equating to about one death every three days (4). Physically active youth have an estimated 2.8 times greater risk of SCA compared to nonathletes of the same age (6). The reported average age for American competitive athletes suffering a SCA is 16.7 years (17). Research has demonstrated adolescent males are at greater SCA risk compared to females (17, 22). Non-traumatic SCA is caused by structural, electrical, or acquired cardiomyopathies and oftentimes has a silent pre-arrest clinical course. A recent study emphasizing the importance of early recognition of cardiac abnormalities noted an absence of cardiac symptoms such as chest pain, shortness of breath, and fatigue prior to arrest in 67% of all sudden cardiac death (SCD) cases (17).

To detect cardiac abnormalities and SCA risk, the American Heart Association (AHA) created the 14-Element AHA Cardiovascular Screening Checklist For Congenital and Genetic Heart Disease for Competitive Athletes (20, 11). This assessment tool includes the following: personal medical history such as cardiac signs and symptoms related to exertion; family history of SCD and cardiac pathology; and physical examination items including HR, physical indicators of Marfan syndrome, and BP (7). It does not include an ECG and therefore may not detect underlying cardiac abnormalities (7). Hypertrophic Cardiomyopathy (HCM), the number one cause of SCA, is difficult to detect with only cardiopulmonary history, family history, and a clinical examination. This is due to 75% of HCM cases not presenting with an audible heart murmur during a resting cardiac exam (21). It has been suggested that the AHA's approach to detecting SCA may fail to detect 90% of at-risk youth (7).

Research suggests certain lifestyle factors such as sleep, diet, and COVID-19 infection may increase SCA risk (9, 8). The Center for Disease Control (CDC) states that routinely accruing less than 7 hours of nighttime sleep negatively impacts exercise recovery, specifically HR variability (8). The CDC also found that drinking at least 5 8-ounce glasses of water daily may decrease SCA risk and ingesting less than 2 glasses per day can increase SCA risk (8). Similar to water intake, vitamin D availability is essential for adequate organ, tissue, and cardiovascular function. As such, inadequate vitamin D intake has been associated with hypertension, congestive heart failure, chronic vascular inflammation, and left ventricular hypertrophy, potentially increasing SCA risk (12). A diagnosis of COVID-19, whether active or recovered, may increase SCA risk. The COVID-19 virus can invade cardiomyocytes or endothelial cells leading to myocarditis, life threatening arrhythmias, acute or chronic heart failure, and even myocardial infarctions (3). In a recent retrospective cohort study of athletes with a COVID-19 history, one-fifth of participants presented with myocardial edema or myocarditis, putting them at increased SCA risk (13).

Early detection of underlying SCA risk factors is essential in reducing the incidence of SCA and SCD in physically active adolescents. Therefore, this study was conducted to determine the prevalence of SCA risk factors in HS athletes and to examine the relationship between these factors, heart health, and SCA risk. This study hypothesized that male HS soccer players would demonstrate underlying SCA risk factors such as abnormal ECG readings as well as elevated resting HR, abnormal BP measurements, dietary and sleep practices known to increase risk, and a history of cardiac symptoms noted on their self-reported surveys. Moreover, this study anticipated seeing an association between the players' ECG readings with COVID-19 history, resting HR, cardiac symptoms, and other risk factors.

METHODS

Participants

This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (16). Members of a boys soccer team, between the ages of 14 and 17 years, at a public HS located in the southeastern United States were recruited for this study using an informational letter. Participants and their parents received written information on all study components including procedures and risks. Parents completed an informed consent document and participants signed an assent form prior to participation. The participating school's research board and the researchers' Institutional Review Board (IRB) provided permission to conduct this study.

A total of 33 soccer athletes (age: 15.8 ± 1.0 years, height: 175.6 ± 7.1 cm, mass: 61.8 ± 7.9 kg) participated. The majority of participants (29/33, 87.9%) self-identified as Caucasian with the remaining four self-identifying as Hispanic/Latino (2/33, 6.1%) and African American (2/33, 6.1%). Almost three-quarters of the players (24/33,72.7%) reported participating in training sessions 5 days per week and most players (28/33,84.8%) reported participating in 2 games per week.

A power analysis was conducted using the ".pwr" package in R studio (*RStudio, PBC*, Boston, MA) to test the difference between independent group means using a two-tailed test, a 0.5 effect size, and an alpha of 0.05. Results showed that one sample study of 33 participants produces a power of 0.795. The effect sizes (Cohen's d) were calculated and evaluated based on the following criteria: < 0.40 trivial, 0.40 to 0.59 small, 0.60 to 0.74 moderate, and > 0.74 large (15).

Protocol

Self-Reported Health Information: Using an online questionnaire (*Qualtrics Research Suite, QualtricsXM™*, Provo, UT), participants provided demographic information and answered questions related to their training loads, medical history, family cardiac history, lifestyle choices, COVID-19 history, heart health, and comfort with reporting cardiac symptoms. Answers were used in describing our participants and identifying the presence of SCA risk factors. To identify potential cardiac pathology, we asked participants if a close family member died from a heart problem before the age of 50 years and if any close family member died from SCD. To determine the incidence of SCA risk factors related to lifestyle, we asked participants to report the average number of hours they sleep each night, the number of water bottles (8 oz bottles) they typically drink each day, and whether or not they ingest vitamin, mineral, or other supplements. We also gathered participants' COVID-19 history by asking participants to report the number of times they were diagnosed with COVID-19 in the past year and a half, the severity of their symptoms, and whether or not COVID-19 symptoms were currently present. To assess personal heart health, we included questions from the AHA's 14-Point History Questionnaire relating to their medical history and symptoms experienced during physical activity such as chest pain, shortness of breath (SOB), and syncope (20).

Electrocardiography: A resting supine 12-lead ECG, (*Welch Allyn Wireless Acquisition Module,* Milwaukee, WI) analyzed the participants' HR, heart rhythm, and electrical heart activity. Participants laid supine on the test table and their skin was prepared for electrode placement by thoroughly wiping the skin with alcohol swabs followed by gentle abrading with gauze. The twelve electrodes (*Welch Allyn Resting ECG Tab Electrodes,* Milwaukee, WI) were positioned according to the recommended placements and synched with the computer software. We collected a minimum of 10 seconds of ECG data along with device generated results including PR intervals (ms), QRS intervals (ms), and QT intervals (ms). The participants were then grouped into one of two categories, abnormal or normal ECG results, based on the 2013 Seattle Criteria as shown in Figure 1 (2).

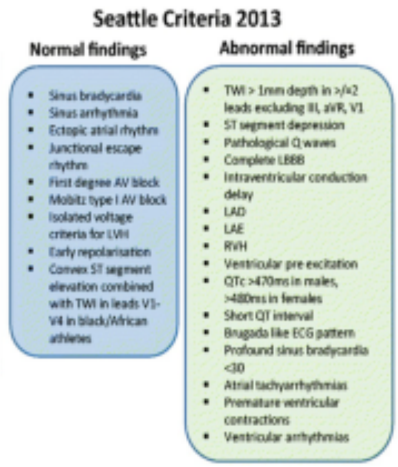

Figure 1. Normal versus Abnormal ECG Findings Based on the 2013 Seattle Criteria (2)

Blood Pressure and Heart Health: We measured seated and supine BP using an automatic BP monitor (*Lazle Electronic Blood Pressure Monitor,* Guangdong, China). To collect this data, participants either sat in the test chair with their back supported and both feet on the ground or laid supine on the test table with both upper and lower extremities extended. In each test position, participants were instructed to remain quiet and breathe normally while the BP cuff was snuggly applied to their bare upper arm. One measurement was obtained in each test position, with a second measurement taken if the initial measurement fell outside normal range limits or appeared abnormal. The average of the two resting BPs was used for data analysis. Two HR measures were gathered. The first was generated by the BP assessment device (*Lazle Electronic Blood Pressure Monitor)* in concert with the participant's seated BP measurement. The second was gathered from the supine 12-lead ECG assessment.

Statistical Analysis

Descriptive statistics including means and proportions were calculated to assess the distributions of the study sample. Numerical variables were summarized through means, standard deviations, and medians with IQR, while categorical variables were reported as percentages. Within group normality of numerical and categorical data was checked using the Shapiro-Wilk test function in R. If one or both groups had a p-value of less than 0.05, the variables were considered nonparametric. If both variables were found to have p-values equal to or greater than 0.05, these parametric variables then underwent the Levene's test in R. Between-group comparisons were assessed including chi-square, Fisher's exact, parametric independent t-tests, and non-parametric Mann-Whitney tests. Odds ratios with 95% confidence intervals for SCA risk were calculated to assess the differences in occurrences of the risk factors of interest for abnormal vs normal ECG results. All calculations and analyses were performed using the free software database R (R-4.2.0 R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Self- Reported Health Information

Demographic information on the participants with abnormal and normal ECG results are presented in Table 1.

Table 1. Demographic Information by Seattle Criteria Group (N=33)

	Abnormal ECG (n=11)	Normal ECG (n=22)
Age (yrs), μ (σ)	15.9 (1.1)	15.7 (1.0)
Height (cm), μ (σ)	177.5 (5.4)	174.7 (7.8)
Weight (kg), μ (σ)	65.0 (5.8)	60.2 (8.4)
Ethnicity: White, # (%)	10 (91)	19 (86)
Ethnicity: Hispanic/Latino, # (%)	1 (9)	1 (5)
Ethnicity: African American, # (%)	0 (0)	2 (9)
Previously been told to have an elevated blood pressure, # (%)	0 (0)	0 (0)
On medications that have been told affect heart rate, # (%)	1 (9)	1 (5)
Had a physical in the past year, # (%)	10 (91)	21 (95)

Family Cardiac Death History: When asked about their family history only 2 participants (2/33, 6.1%) indicated a close family member died from a heart problem before the age of 50 years. No participants indicated having a close family member die from SCA.

Lifestyle Factors: Participants responded to 11 questions on lifestyle choices associated with SCA risk which are presented in Table 2. The largest differences between groups was found in the participants who trained more than 5 days each week and ate red meat regularly. Almost half of participants (15/33, 45.5%) indicated drinking 3 or fewer 8 oz water bottles per day. Less than a third (10/33, 30.3%) indicated taking a vitamin and/or mineral supplement including vitamin B-12, vitamin C, vitamin D, fish oil, creatine, and protein powder. Seven of the 11 participants in the abnormal ECG group reported not getting the recommended amount of nightly sleep compared to the normal ECG group (7/22). Daily water and vitamin intake was similar between groups.

COVID-19 History: Thirteen (39.4%) participants reported testing positive for COVID-19 from November 2020 to March 2022 as shown in Table 2. The majority of participants with a positive COVID-19 history had mild symptomatology while 1 participant reported severe symptoms. Five participants (15.2%) reported symptoms persisting after the initial disease period.

Table 2. Lifestyle Information by Seattle Criteria Group (N=33)

	Abnormal ECG, # (%) (n=11)	Normal ECG, # (%) (n=22)
Training more than 5 days per week	9 (82)	17 (77)
Play other sports throughout the year	7 (64)	8 (36)
Play other sports or on other teams during the same season	2 (18)	2 (9)
Eat salmon	7 (64)	13 (60)
Eat red meat	10 (91)	18 (82)
Consumed energy drink in the 3 hours prior to testing	1 (9)	1 (5)
Unhealthy water intake	5 (46)	10 (46)
Vitamin intake	3 (27)	7 (32)
Unhealthy sleep	7 (64)	7 (32)
Positive COVID-19 history	8 (73)	5 (23)
Felt COVID-19 symptoms after initial infection period	4 (36.4)	1 (4.6)

We determined the association of COVID-19 history with HR and BP measurements (Table 3). A systolic BP above 130 mmHg and a HR above 100 bpm are considered elevated. Three participants had an elevated seated HR, with two of these participants reporting a COVID-19 history. However, as shown in Table 3, the relationship between COVID-19 history and elevated HR was not statistically significant (p=0.31, d=0.74). Additionally, our analysis determined a positive COVID-19 history does not impact seated or supine BP (p=0.21 and p=0.74 respectively with d=0.47).

Table 3. Association between COVID-19 and Elevated Heart Health Values

	Positive COVID History, # (%) (n=13)	Negative COVID History, # (%) (n=20)	P-Value	Cohen's D Effect Size
Elevated Seated Heart Rate	2 (15.4)	1 (5.0)	0.31	0.74
Elevated Supine Heart Rate	0 (0.0)	0 (0.0)	NA	1.12
Elevated Seated Systolic BP	1 (7.7)	5 (25.0)	0.21	0.47
Elevated Supine Systolic BP	2 (15.4)	4 (20.0)	0.74	0.47

Heart Health: The AHA 14-Point History Questionnaire was referenced to compile questions for the participants regarding their signs and symptoms, personal history, and family history related to SCA. Over 50% of participants reported experiencing SOB with exercise and approximately 30% reported experiencing chest pain that caused them to stop exercising. Interestingly, a fifth of participants (21%) indicated having prior cardiac testing (Table 4).

Table 4. Heart Health Information by Seattle Criteria Group (N=33)

	Abnormal ECG (n=11)	Normal ECG (n=22)
Have passed out during exercise, # (%)	0 (0)	2 (9)
Have had chest pain during exercise, # (%)	3 (27)	6 (27)
Have had shortness of breath during exercise, # (%)	6 (55)	10 (46)
Been told has heart murmur, # (%)	1 (9)	1 (5)
Heart test in the past, # (%)	3 (27)	3 (13.6)
Seated heart rate (bpm), μ (σ)	71.6 (13.6)	73.8 (13.1)
Supine heart rate (bpm), μ (σ)	65.7 (13.2)	71.4 (12.6)
Seated systolic blood pressure (mmHg), μ (σ)	123.7 (9.3)	122.3 (10.0)
Supine systolic blood pressure (mmHg), μ (σ)	121.0 (8.7)	118.4 (13.1)

Comfort with Reporting Symptoms: Participants were asked to respond to questions evaluating their comfort discussing health concerns with their coach or athletic trainer. The majority, 93.9%, of participants (31/33) responded "yes" to feeling comfortable discussing injuries or general pain with their coach or athletic trainer. Fortunately, 87.9% of participants (29/33) indicated being comfortable telling their coach or athletic trainer when they are experiencing chest pain or discomfort.

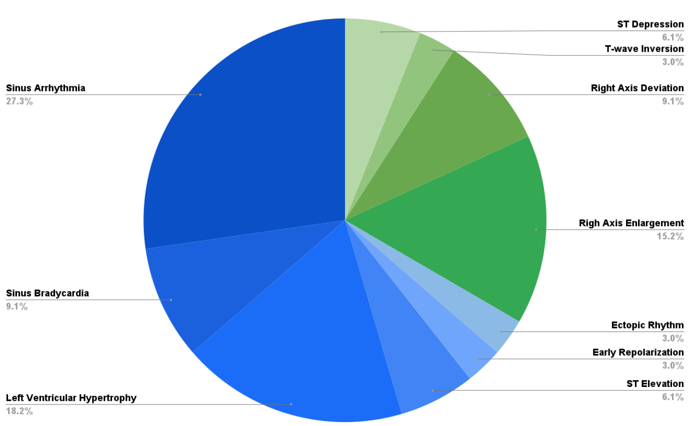

Figure 2. Normal and Abnormal ECG Findings (N=33)

Electrocardiography

Employing the 2013 Seattle Criteria, we categorized participants' ECG findings into one of two groups, normal or abnormal (2). The ECGs of 11 participants (33.3%) were considered abnormal. Participants in this category (green) presented with the following: ST segment depression (6.1%), T-wave inversion (3.0%), right axis deviation (9.1%), and right axis enlargement (15.2%) (Figure 2).

The PR, QRS, and QT intervals were assessed between those with abnormal and normal ECG results as shown in Table 5.

Table 5. Electrocardiogram Information by Seattle Criteria Group (N=33)

	Abnormal ECG, μ (σ) (n=11)	Normal ECG, μ (σ) (n=22)
ECG: PR Interval (ms)	154.0 (21.9)	142.8 (13.7)
ECG: QRS Interval (ms)	101.4 (8.5)	94.6 (6.3)
ECG: QT 1st Unit of Interval (ms)	401.7 (32.1)	381.9 (26.2)
ECG: QT 2nd Unit of Interval (ms)	410.1 (16.0)	401.7 (13.2)

Participants' answers to survey questions related to demographic and lifestyle factors associated with SCA risk, COVID infection history and symptomatology, and their heart health history for both the abnormal and normal ECG groups are presented in Table 6. Over half of the participants (6/11) in the abnormal ECG group reported experiencing SOB during exercise and almost a third (3/11, 27.3%) reported having experienced chest pain during exercise.

Of the 11 participants with abnormal ECGs, 8 (72.7%) had a positive COVID-19 history with one reporting experiencing symptoms after the initial infection period. A positive COVID-19 history ($p=0.01$, $d=1.17$) and feeling the COVID-19 symptoms after the initial symptomatic period ($p=0.02$, $d=0.98$) were both found to be statistically significant between those with abnormal ECG versus normal ECG results. Furthermore, those with a positive COVID-19 history are 8.14 times more likely to have an abnormal ECG.

Mean HR and BP measurements along with ECGs for both the abnormal and normal ECG group were assessed and are presented in Table 7. While most measurements are similar between the ECG groups, a bivariate comparison demonstrated a significant difference in QRS interval to abnormal ECG ($p < .05$). In addition, a significant correlation was found between having experienced chest pain during exercise and having an abnormal ECG.

Table 6. Bivariate Comparisons of Demographic and Lifestyle Information by Seattle Criteria Group (N=33)

	P-Value (Abnormal vs Normal ECG)	Cohen's D Effect Size	Unadjusted Odds Ratio
Age (yrs)	0.56	0.22	NA
Height (cm)	0.30	0.40	NA
Weight (kg)	0.09	0.64	NA
Ethnicity: White	0.71	0.14	1.00, (0.11, 91.02)
Ethnicity: Hispanic/Latino	0.61	0.19	1.00, (0.02, 172.29)
Ethnicity: African American	0.30	0.39	0.54, (0.00, 10.79)
Training more than 5 days per week	0.76	0.11	1.27, (0.21, 11.51)
Immediate family member died of heart problem	0.04	0.82	0.10, (0.39, ∞)
Immediate family member died of SCA	NA	NA	NA
Unhealthy water intake	1.00	NA	NA
Vitamin intake	0.47	0.32	1.00, (0.01, ∞)
Unhealthy sleep	0.08	0.68	0.14, (0.65, 23.02)
Positive COVID-19 history	0.01	1.17	NA
Felt COVID-19 symptoms after initial infection period	0.02	0.98	0.03, (0.90, 615.50)

Table 7. Bivariate Comparisons of Heart Health Information by Seattle Criteria Group (N=33)

	P-Value (Abnormal vs Normal ECG)	Cohen's D Effect Size	Unadjusted Odds Ratio
Have passed out during exercise	0.30	0.39	0.54, (0.00, 10.79)
Have had chest pain during exercise	0.04	NA	1.02, (0.17, 5.21)
Have had shortness of breath during exercise	0.62	0.18	1.42, (0.32, 6.56)
Been told to have heart murmur	0.61	0.19	1.00, (0.02, 172.29)
Heart test in past	0.34	0.36	0.38, (0.25, 21.27)
Seated heart rate (bpm)	0.41	0.17	NA
Supine heart rate (bpm)	0.24	0.46	NA
Seated systolic blood pressure (mmHg)	0.69	0.15	NA

Supine systolic blood pressure (mmHg)	0.56	0.46	NA
ECG: PR Interval (ms)	0.08	0.69	NA
ECG: QRS Interval (ms)	0.02	0.98	NA
ECG: QT 1st Unit of Interval (ms)	0.08	0.70	NA
ECG: QT 2nd Unit of Interval (ms)	0.12	0.61	NA

DISCUSSION

We conducted this investigation to determine the incidence of known risk factors for SCA in HS athletes and the relationship between these risk factors and heart health. Our results revealed that when exercising, over 50% of our participants experienced SOB and over 30% felt chest pain. We also determined that endorsing chest pain with exercise was associated with abnormal ECG findings. Almost 40% of our participants reported a COVID-19 infection history with some reporting persisting symptoms. A small number demonstrated elevated resting HR and/or BP measurements. A third of our study participants had abnormal ECG findings, and of these, over 70% reported a positive COVID-19 infection history. From statistical analysis, we determined persons with a positive COVID-19 history are 8.14 times more likely to present with an abnormal ECG. Additionally, participants overall complied with lifestyle behaviors suggested to decrease SCA risk, reported feeling comfortable informing their coach or athletic trainer when experiencing potential SCA symptoms, and presented with normal resting HR and BP measurements. Even though a very small percentage of our participants noted a family history of heart problems, we identified a significant association between having a family member die from a heart problem and having an abnormal ECG.

Oftentimes, PPS for SCA risk in young athletes is focused on cardiopulmonary symptoms such as chest pain, SOB, and syncope during exercise. Our study determined that during exercise 30.3% of our participants experienced chest pain, 51.5% experienced SOB, and 6.1% experienced passing out (syncope). These results are similar to Chatard's study of SCA risk in young athletes, in which the most frequently reported symptoms were "more breathless than teammates" (9.8%), "chest pain" (6.5%), and "dizziness during exercise" (6.4%) (5). It is important to note that over two-thirds of our study participants reported experiencing at least 1 cardiovascular symptom with the majority (87.9%) of our participants reporting feeling comfortable discussing these symptoms with their coaches and/or athletic trainer. This finding emphasizes the importance of SCA education, particularly programs focused on informing coaches, players, and others associated with youth sports and physical activity about the risk factors for SCA. Feeling chest pain during exercise directly correlated with having an abnormal ECG finding, and thus, increases the participants' risk for SCA. This suggests that in addition to physical examination and collecting information on cardiac symptoms experienced during exercise, as the AHA currently recommends, an ECG assessment be included in a PPS, especially for individuals reporting a history of chest pain during exercise.

Determining COVID-19 presence is an important aspect in redefining PPS. A COVID-19 infection increases susceptibility for myocardial infarction, myocarditis, arrhythmias, and stress cardiomyopathies which exacerbate SCA risk (19). Current recommendations for RTP following COVID-19 infection vary. In their post-COVID-19 infection working group paper, McKinney et al recommended athletes with a symptomatic COVID-19 infection start their RTP screening with an ECG (13, 14). However, other organizations suggest an ECG only be completed if the athlete has an abnormal troponin level (14, 1). In an AHA consensus statement, Ruberg et al discusses the concept of cardiac triad testing in relation to acute cardiac inflammation following COVID-19 infection if the athlete has at least one cardiopulmonary symptom (19). The triad includes an ECG, cardiac troponin measurement, and transthoracic echocardiogram for athletes with COVID-19 symptoms (19). The intended outcome with the cardiac triad testing is that an ECG is able to identify altered cardiac function compared to pre-infection values. A magnetic resonance study conducted by Malek et al demonstrated sustained cardiovascular involvement after COVID-19 recovery in a significant number of participants with both asymptomatic and symptomatic infection courses (13). Our study findings demonstrate that a positive COVID-19 history as well as persistent COVID-19 symptoms are related to abnormal ECG readings, therefore, suggesting that ECG's should be considered an integral part of PPS. Our study found no statistical significance between COVID-19 infection and elevated BP or HR measurements, however, this further illustrates the need to incorporate an ECG to detect SCA risk.

Prior studies have shown family history is not always predictive of future arrhythmic events, including SCA. In a recent study on HS athletes, 24% of participants reported a family history of cardiac arrest (4). This percentage is much higher than we identified in our participants (2/33,18.2%), however both (100%) presented with an abnormal ECG. Similarly, the ECGs of 30% of our participants revealed prolonged QRS durations (>100ms) which is higher than previously reported (10). An increased QRS interval is the most common ECG abnormality detected in patients with HCM, a condition associated with SCA and the leading cause of SCD in young athletes (10). The ECG findings in our study reinforce the importance of including family history questions into PPS, in concert with an ECG.

This study is not without limitations. Participants were all males, predominantly Caucasian, and from a single HS in a relatively affluent geographic area, which limits results generalizability. Also, a high percentage of the study data was collected through a survey participants completed without input from parents or other adults. Therefore, recall bias and question understanding may have influenced participant response accuracy.

This study explores the incidence of known SCA risk factors and their associations to abnormal ECG readings. Completing a family history, cardiac history, and physical exam as recommended by the AHA is essential in reducing the incidence of SCD in young athletes, however, the AHA's current method may fall short of identifying athletes at risk for SCA. Incorporating an ECG into PPS increases the ability to detect the cardiomyopathies accounting for about two-thirds of SCA in US competitive athletes (17). Because COVID-19 increases an athlete's susceptibility for myocarditis and other cardiac abnormalities, an ECG should be included in both PPS and RTP guidelines, especially for those reporting prolonging symptoms. Overall, this study provides insights into SCA risk in HS athletes and supports incorporating ECG assessments into both PPS and RTP protocols.

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