

Cost and yield of adding EKG to history and physical in screening division I intercollegiate athletes: A five-year experience

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Abstract:

Objectives: We sought to determine the cost and yield of a five-year EKG screening program at a United States Division I College.

Background: EKG screening of intercollegiate athletes is controversial in part because the costs and yield are not well defined. Both the AHA and ESC have different criteria for screening, in part because the populations being screened are different.

Methods: At the University of Virginia all 1473 competitive athletes over 5 years were screened with history and physical (H&P) and EKGs using European Society of Cardiology (ESC) guidelines with follow-up testing as dictated by clinical symptoms and EKG findings.

Results: H&P alone uncovered 5 significant cardiac abnormalities. EKGs were abnormal in 275 (19%) resulting in 359 additional tests. Additional testing confirmed eight significant cardiac abnormalities that were not found by H&P. These included 1 bicuspid aortic valve, 4 rapidly conducting accessory pathways, 1 long-QT patient, 1 with frequent PVCs and low EF, and 1 patient with frequent PVCs but normal EF. There were no cases of hypertrophic cardiomyopathy found. The total cost of the program was US \$894,870. The cost of H&P screening alone was \$343,725 or \$68,745 per finding while the marginal cost of adding EKG screening including resulting tests and procedures was US\$551,145 or US\$68,893 per additional finding.

Conclusions: EKG screening of US college athletes can uncover significant cardiac pathology not discovered by H&P alone. Although EKG screening also results in many false positives resulting in additional tests, the overall cost per diagnosis of adding EKG screening is similar to H&P screening alone.

Keywords: Athletes, Screening, EKG, Ventricular Tachycardia, Atrial Fibrillation, Wolff-Parkinson White, Supraventricular Tachycardia

Abbreviations:

History and Physical: H&P

EKG: Electrocardiogram

ESC: European Society of Cardiology

AHA: American Heart Association

PVC: Premature Ventricular contraction

HCM: Hypertrophic Cardiomyopathy

LVH: Left ventricular hypertrophy

EPS: Electrophysiology study

## **Introduction**

Pre-participation athletic screening with electrocardiograms (EKG) is controversial. While European Society of Cardiology (ESC) guidelines (1) recommend pre-participation EKGs in addition to history and physical (H&P) in all competitive athletes below age 35, the American Heart Association (AHA) (2,3) in the United States recommends only H&P without EKG. The rationale for these two recommendations rests on disparate findings regarding cost and yield. One potential reason for this is that the US is more ethnically diverse and thus has a lower prevalence of any given genetic condition. For example, in Italy, the genetic predisposition to arrhythmogenic right ventricular cardiomyopathy (ARVC) may be higher than in the United States (4). The US population has grown more diverse in recent years, and there are little data in the modern era on the cost and yield of EKG screening in a US college population. The few studies that exist include fewer than 600 patients (5). At the University of Virginia (UVA), we have performed EKG screening in all 1473 competitive athletes since 2005. We report the yield and cost of an EKG screening program in addition to H&P in a NCAA Division I college athlete population.

## Methods:

From 2005 until 2010, all 1473 NCAA Division I athletes regardless of sport were screened with history and physical (H&P) and EKGs. H&P was performed by a of team physicians, including two internists with input from a cardiologist. Tests including echocardiograms were ordered as dictated by the H&P.

Then, an EKG was performed and reviewed by an internist and over read by a cardiac electrophysiologist. A prospectively-defined protocol based was used to guide additional testing and athletic restrictions (Figure 1). The protocol directed additional testing including transthoracic echocardiograms (TTE), magnetic resonance imaging (MRI), treadmill stress testing, and drug challenges. Findings were defined as new information requiring procedures, periodic follow-up testing, or exclusion from athletic participation.

On the screening EKG, LVH criteria were taken from the ESC recommendations and included an R or S wave in a standard lead  $> 2\text{mV}$ , S wave in lead  $V_1$  or  $V_2 > 3\text{ mV}$  or an R wave in  $V_5$  or  $V_6 > 3\text{ mV}$  (1). If patients met these criteria, an echocardiogram was performed either at UVA or by the athlete's local physician to rule out hypertrophic cardiomyopathy (HCM). In order to differentiate HCM from athletic heart, two cardiologists with extensive experience in echocardiography examined echocardiograms to rule out left atrial dilation, abnormal diastolic function, and LV thickness  $> 12\text{ mm}$  (5). If none of these criteria were met, and there was no history of exercise-induced syncope, the patient was declared not to have HCM. We did not detrain any athletes to see if LVH regressed.

While the University of Virginia paid for all H&Ps and EKGs, the costs of imaging studies were typically paid for by the athlete's insurance. As a result, if insurance companies refused MRI exams, echocardiograms were done first, and then MRI was done. Further, some insurance companies would only pay for echocardiograms done locally and images sent to UVA. All students were required to undergo the recommended tests to participate.

## Cost analysis

Staff salaries and EKG machines were paid for by UVA. Using salaries with benefits, we calculated a five year personnel cost of \$192,000 for the H&P screening program (10% of the salary and benefits for each of two internists per year for 5 years.) The five-year personnel cost for EKG screening was \$176,100 (5% of additional salary for each internist, 2% per year of an electrophysiologist's salary, and \$40,000 for technicians for 5 years). UVA purchased two EKG machines for \$10000 each. We assumed these machines depreciated at 10% per year giving a five-year cost of \$14,095.

While most follow-up studies were paid for by insurance, these costs were included in our cost analysis. To estimate these costs we used the average collection from insurance companies at UVA for the athlete population. The reimbursement for an echocardiogram was \$900, MRI \$1000, drug challenge \$1200, Holter studies \$175, treadmill stress test \$300, EP study \$25000. We prospectively defined significant cardiac finding as any finding that required invasive therapy or interval follow up testing (eg. annual echocardiogram). We then took the total cost of the program (including follow up

tests) and divided it by the number of significant cardiac findings to determine a cost per finding.

Statistical analysis using univariate ANOVA was performed using PASW Statistics 18.0 (SPSS, Chicago, IL). This study was approved by the University of Virginia Institutional Review Board.

Results:

#### *Athlete Demographics*

Demographic information of athletes screened is shown in Table 1. Seven hundred forty-one (51%) were women. Racial distribution was white (71%), African-Americans (12.9%), Asians (2%), and Latinos (2%.) Ninety percent had no prior medical conditions and 978 (66%) were taking no prescription medicines. Thirty athletes were taking medications for attention deficit hyperactivity disorder, including adderall.

Two athletes had undergone ablation procedures in the past, both for symptomatic accessory pathways.

#### *Results of History and Physical and subsequent testing*

History and physical examination identified 87 athletes with a history of potential cardiac complaints. Sixty-one of these had full cardiac workups prior to arrival at UVA (including echocardiogram) that were negative and had no further testing at UVA. The other 26 had a normal EKG and echocardiogram at UVA. Five of these athletes had symptomatic palpitations. Event recorders documented narrow complex tachycardia. All five athletes subsequently underwent electrophysiology studies (EPS), which identified three patients with AVNRT, one with an atrial tachycardia from near the coronary sinus, and one right inferior pulmonary vein tachycardia presenting with AF. All underwent successful ablation. None had a negative EP study. Thus, H&P alone prompted 26 EKGs, 26 echos, and 5 EP studies which led to the discovery of 5 potentially significant cardiac abnormalities.

#### *EKG and follow-up test results*

EKGs were abnormal in 443(30%). (Figure 2) The total number of abnormal findings exceeds the total number of abnormal electrocardiograms as some EKGs had multiple abnormal findings.

We identified 253 athletes with EKG criteria suggesting left ventricular hypertrophy. All received an echocardiogram (227 at our institution). No echocardiograms had evidence of hypertrophic cardiomyopathy. However, one athlete was found to have a bicuspid aortic valve with mild aortic regurgitation.

We found no relationship between sport intensity, ethnic origin, and LVH findings on EKG, even though 43% of the athletes were doing high intensity athletics (383 females and 254 males). Gender was the only factor that predicted LVH.

Incomplete right bundle branch block (iRBBB) with inverted T waves in V<sub>1</sub>, V<sub>2</sub>, or V<sub>3</sub> occurred in 88 athletes including 70 with QRS width greater than 100 ms. As a

result, 44 MRI examinations were performed. The 36 remaining patients had echocardiography in lieu of MRI exams due to insurance coverage or cost issues. No patient had evidence of arrhythmogenic right ventricular cardiomyopathy on the MRIs nor was RV dilation seen on echo. No athletes were excluded from athletic participation based upon T wave inversion.

EKGs identified 4 athletes with short PR intervals and delta waves. All were asymptomatic. All underwent exercise testing that showed exaggeration of the delta wave and thus underwent EPS. During EPS all 4 pathways had refractory periods of less than 250ms and were successfully ablated given data suggesting short refractory periods being associated with high risk of sudden death (6). Two also had inducible AF prior to ablation, but not after ablation. None were restricted after ablation.

Six athletes had multiple PVCs on EKG and underwent exercise stress testing, holter monitoring, and MRI. No student had symptoms. Four patients had fewer than 10% PVCs on 24 hour monitoring, normal MRI, and no increase in PVCs with exercise and were allowed to compete without restriction or further testing. One athlete had unifocal PVCs 28% of the day by holter monitoring but had a reduction in PVCs with exercise and a normal ejection fraction. Because of a normal exercise test, this patient was cleared for athletics but will have annual echocardiography to follow the ejection fraction. The sixth patient had multifocal PVCs 48% of the day by holter monitor, although PVCs decreased with stress testing and the ejection fraction was normal by echocardiography. Due to the multifocal PVCs (Figure 3), this athlete was excluded from further athletic participation. Follow-up testing demonstrates that over one year, the ejection fraction has declined from 65% to 40%. This athlete remains excluded from athletic participation and is to undergo further evaluation.

A total of 4 athletes were found to have prolonged QT intervals. These athletes were subjected to epinephrine challenges. QT interval increased in one student and genetic screening confirmed Long QT1. This athlete was excluded from further athletic participation. We did not identify any athletes with short QT intervals.

Three athletes had coved ST segments on EKG and underwent procainamide challenges. None of these studies were positive for Brugada syndrome.

In summary, EKG screening found 8 significant cardiac findings including 4 asymptomatic pathways, 1 patient with frequent PVCs and low EF, 1 patient with frequent PVCs and normal EF (requiring annual echocardiography), 1 Long QT patient, and 1 patient with a bicuspid aortic valve. Two of these students were excluded from athletics permanently.

#### *Summary of screening findings*

Overall H&P alone suggested arrhythmias in 5 patients that were confirmed on electrophysiologic study (EPS) including one right inferior pulmonary vein tachycardia, 3 atrioventricular nodal reentrant tachycardias, and one coronary sinus atrial tachycardia. Addition of EKG added 8 diagnosis including 1 bicuspid aortic valve, 4 accessory pathways, 1 LQT patient, 1 frequent PVC with normal EF, and 1 frequent polymorphic PVCs with low EF. Two students were barred from athletic participation due to asymptomatic EKG findings.

Costs:

Overall the screening program cost our institution or insurance companies \$894,870 and found 13 significant cardiac findings for a cost per finding of \$68,836.

The cost of the H&P only program including 26 clinically indicated EKG (\$1300), 3 Holter monitors (\$525), 26 echocardiograms (\$23,400), excluding those echocardiograms done prior to coming to UVA, salaries (\$192,000), and 5 EPS with ablations (\$125,000) was \$343,725. With this method alone we found 5 abnormalities. Thus the cost per significant cardiac finding of H&P alone was \$68,745.

The marginal cost of adding EKGs to screening (including follow-up testing and ablations) was \$551.145, including 1463 electrocardiograms (cost of \$14,095 for an EKG machine and \$40,000 for technicians), 227 echocardiograms (\$204,500), 44 MRIs (\$44,000), 10 stress tests (\$3,000), 7 drug studies (\$8,400), 6 Holter monitors (\$1050), 4 ablations (\$100,000), and the physician cost (\$136,100). EKG identified 8 asymptomatic findings that required either therapy (4) or regular follow-up (4). Thus, the marginal cost of EKGs per diagnoses was \$68,893.

#### Discussion:

In a 5-year experience, we have demonstrated that adding EKGs to an athletic screening program discovers significant pathology in Division I college athletes at a cost per significant cardiac finding that is similar to H&P alone. While adding EKG to H&P did increase the cost, the yield increased proportionately. Thus, the overall program cost per diagnosis was similar to the cost per diagnosis for H&P or EKG screening alone.

Although other studies have been reported, our study differs in significant ways. First our study is significantly larger with 1473 patients as opposed to 510 in the largest previously reported study in American collegiate athletes. Second, Baggish et al (5) evaluated H&P compared to EKG and echocardiography in a blinded fashion and found that EKG and echocardiography identified more abnormalities than H&P alone, but prompted more testing. Our report describes the costs and results of an active clinically-oriented screening program rather than a research protocol. Thus, the H&P combined with EKG drove follow-up tests. Third, our study ran for a longer time period, which gave us more follow-up. Fourth, our program only performed echocardiograms as guided by the EKG and H&P which may reduce costs. Fifth, because our program was funded internally or with insurance reimbursement we were able to provide accurate costs. Finally, our population may represent a more elite athletic population based upon the fact that 65% of our athletes were on athletic scholarship as opposed to studies done at another college that has no athletic scholarships.

Our findings are different than results of a recent study by Baggish et al (5) and are more consistent with a prior study on athletes who underwent both EKG and echocardiography in England. This study demonstrated very few athletes with echocardiographic and EKG findings suggestive of HCM using the Sokolow-Lyon criteria (7). Only 0.09% of athletes in that cohort had both EKG and echocardiographic findings suggestive of HCM. However, it is unclear how many in the English cohort had

EKG criteria suggestive of LVH but echocardiographic findings that did not support the diagnosis.

We found no patients with HCM, in part perhaps because we did not do echocardiograms in all patients. However, given data that EKGs are highly sensitive for HCM(8), it is unlikely that we missed HCM. However, other reports indicate that HCM may develop over prolonged periods of time (9). To truly diagnose the specificity and sensitivity of the ESC criteria for disease in a US athlete population would require echocardiography on all athletes and could potentially require serial echocardiography. Thus, it remains unclear what the true sensitivity and specificity of EKG for cardiac diagnoses are in this population. While we did not perform echocardiography on all participating athletes, our practice reflects a more common, real world protocol, since EKGs are more readily available than echocardiograms.

We did find one patient with a bicuspid aortic valve who will require periodic echocardiograms. Furthermore, we discovered two patients with frequent PVCs (>10%) including one who developed a low EF, 4 patients with asymptomatic accessory pathways, as well as one patient with genotype-confirmed long QT. Other studies have not identified these findings with EKG screening. Since all these findings are rare it is possible that these differences are due to the small sample size of most studies. In that case our study is important in that it shows the different kinds of findings that can be found on screening EKGs.

In contrast to other studies, we excluded only 2/1473 (0.14%) athletes which is less than a smaller study that excluded 3/508 (0.60%)(5) , this difference maybe because we provided aggressive EP therapy to most patients with abnormalities. If this definitive therapy was not provided, we would have excluded 7/1473 based upon EKG criteria alone and 11/1473 based upon EKG and symptoms, making the percentage excluded similar to other studies.

We identified a total of thirteen abnormalities that required intervention. Of these, five were suggested by history and physical and confirmed and treated by further testing. Eight asymptomatic abnormalities were suggested by EKG and confirmed with further testing.

The athlete with polymorphic PVCs and an initially normal heart was excluded from further athletic participation based upon the 36<sup>th</sup> Bethesda conference, and continued participation of the athlete with monomorphic PVCs that declined with exercise is supported by the same guidelines(10) . These guidelines also recommend that athletes with LQT1 may continue to participate in athletic activities, other than swimming. However, there is controversy regarding further athletic participation in this population. NASPE guidelines from 2001(11) suggest restricting athletes with LQT1. This disagreement in expert opinion points to the fact that for many of the diagnoses identified in this population there are no clear guidelines on management. Our patient would have been allowed to continue under the Bethesda guidelines as the QT was less than 480 ms but would have been barred from participation under the NASPE guidelines. We choose to exclude this patient after consulting two other centers and after a long discussion with the student.

Our testing protocol differs significantly from those that have been previously described in the US athlete population. Our results demonstrate that using the ESC criteria to evaluate US athletes is likely to identify disease, but also to generate a

significant number of false positive tests. However, the bulk of the guidelines on EKG interpretation in this population are based upon findings in Italian athletes, whose genetic predispositions may be different from athletes in the US, which is racially more diverse. Thus, the yield of these criteria in a US population is unclear. Our study suggests that the criteria produce a significant number of false positives, but also a significant number of important diagnoses. Our protocol may need to be modified to account for the EKG criteria as described in a recent position paper by Corrado et al. (12).

While prior studies have compared LVH findings on EKG in athletes compared to non-athletes, we examined our data to determine whether sport intensity predicted EKG findings of LVH. We did not identify a relationship between ethnic origin, sport intensity and LVH findings. Only male gender was a significant predictor of LVH.

It is interesting that in our series of 1473 young athletes screened by H&P, family history and EKGs we found no cases of HCM. Many series report an incidence of HCM of 0.2% (8). Furthermore, the incidence in African-Americans is higher(13), and our population included 15% African-Americans. One possibility is that we missed some HCM patients since we did not do echocardiograms in every student as the Baggish et al did. However, the sensitivity of using these EKG criteria is thought to be as high as that of echocardiography(1). Furthermore, we did echocardiograms in 253 patients with LVH on EKG or any history of syncope or a murmur consistent with HCM on exam and found no HCM. Since HCM often presents in the 40s (14) and the mean age of our patients was 17 we may have missed HCM. Another possibility for having no HCM in our series is that HCM is simply rarer than suggested by other series.

The total cost of our screening program (including follow up tests) was \$894,870 to diagnose 5 symptomatic and 8 asymptomatic findings or \$68,836 per diagnosis. The cost of the H&P program alone would have been \$68,745 per diagnosis. The cost of the EKG portion of the program was \$68,893 per finding. Thus, the costs per diagnosis associated with each strategy were similar. However, adding EKG screening excluded 2 asymptomatic patients with potentially lethal conditions and allowed us to definitively treat 4 arrhythmias that were also potentially dangerous (6). Furthermore, we will continue annual echocardiography on one athlete due to frequent PVCs.

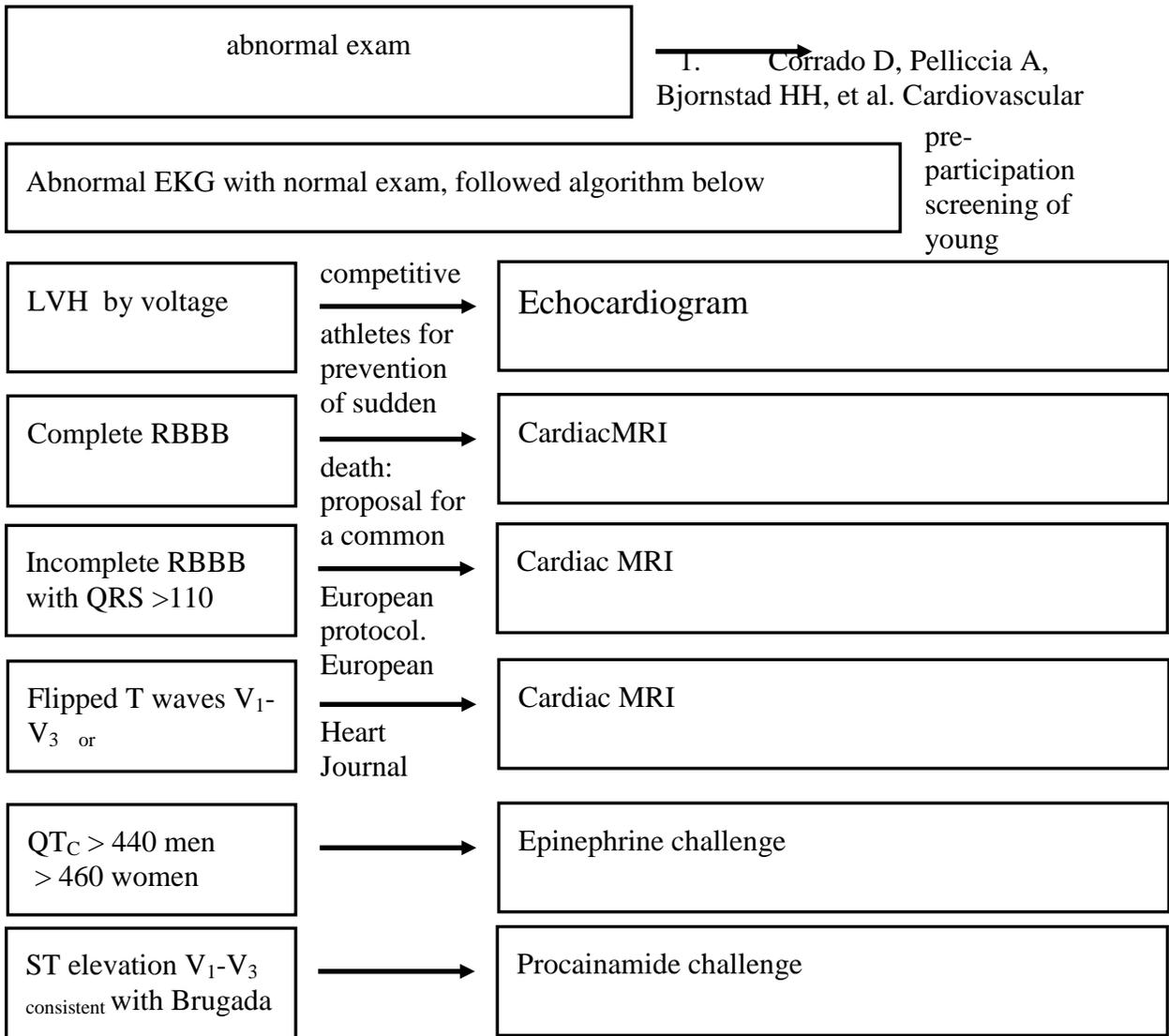
The EKG screening program found 8 additional cardiac conditions that could have impacted a student's athletic career or health. Six of these were treatable. Thus, the cost of EKG screening may be justified especially since the cost per finding for the H&P alone strategy was similar to adding EKGs. Furthermore, the bulk of the cost in the EKG-based screening process was full echocardiograms to exclude HCM in students whose EKG met LVH criteria. It is possible that by using limited echocardiograms that are targeted to septal thickness, the cost of EKG screening may drop considerably. It is possible that more specific EKG criteria for HCM may reduce the need for echocardiograms. However, in our study we had no HCM patients so we cannot say what EKG criteria would maximize specificity without sacrificing sensitivity.

EPS were the most expensive test per diagnosis. However, this test was the most revealing and allowed for definitive therapy in the 4 patients who underwent ablation for a potentially life-threatening pathway (6). There were no negative EPS.

## Limitations

A previous analysis of athletic screening in the US athlete population involved blinded analysis of H&P, EKG, and echocardiography (5). Our study was not blinded and thus the results of H&P may have affected the EKG reading. However, this reflects a real world practice of using multiple pieces of information to guide care. We did not formally follow our athletes beyond college and it is possible some developed HCM after college.

In conclusion, EKG screening of elite collegiate athletes increased the cost of screening due to false positive EKGs, but identified 8 cardiac abnormalities, 6 of which required intervention and 2 of which required discontinuation of athletic participation. The cost per diagnosis suggested by H&P alone was similar than the cost per diagnosis identified by EKG.



2005;26:516-524.

PVCs, being placed on hold, Holter, Cardiac MRI, Treadmill stress test	
Heart block	→ Treadmill stress test
Short PR interval with Delta wave	→ Ablation if confirmed

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Figure 1. This algorithm depicts the EKG abnormality identified and the subsequent testing performed.

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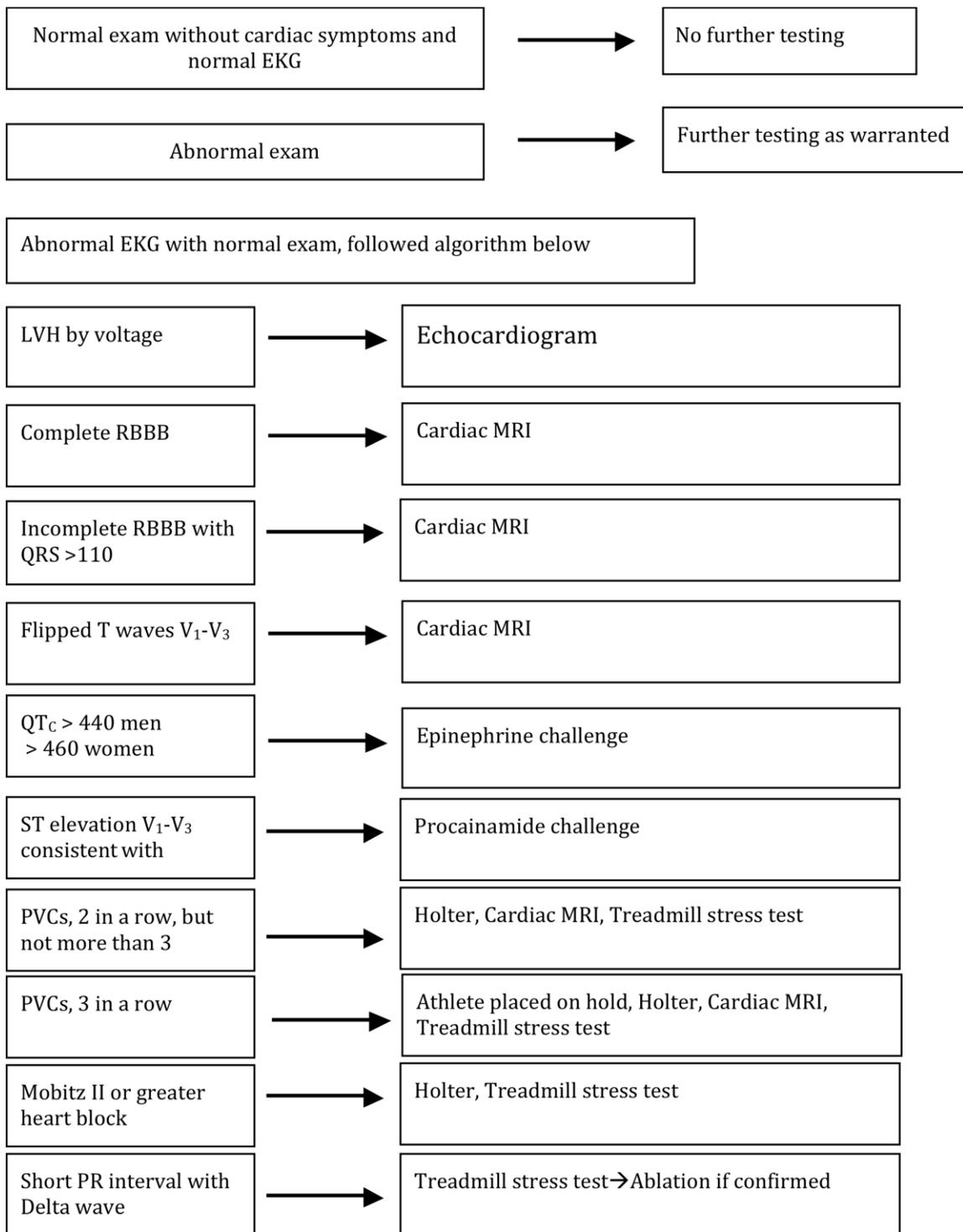


Figure 1. Testing algorithm. This algorithm depicts the EKG abnormality identified and the subsequent testing performed.

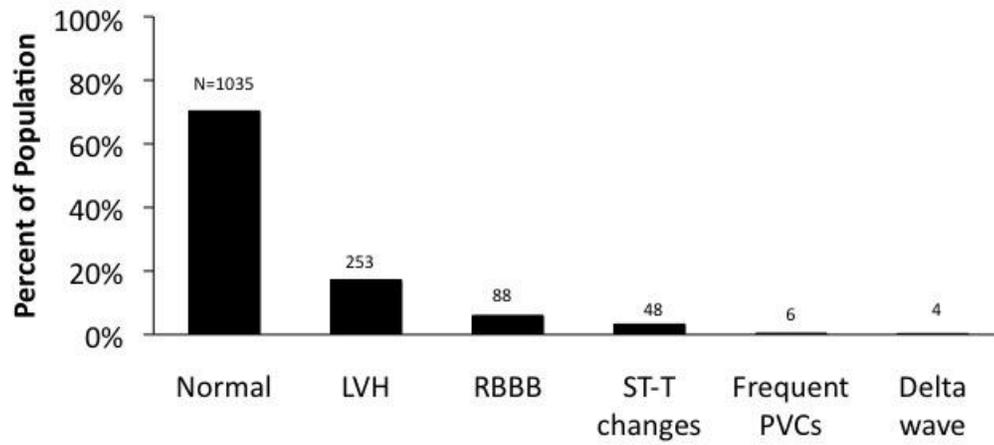


Figure 2. EKG abnormalities. Distribution of abnormalities identified by EKG criteria.



Figure 3. Athlete EKG. This EKG was obtained at the initial screening on an athlete subsequently found to have polymorphic PVCs with exercise and, a year later, a reduced ejection fraction. This athlete was barred from further competition and was recommended to refrain from athletics.

Table 1. Athlete demographics

	Male	Female
Number	732	741
Age	19	19
BMI	25	22
SBP	132	124
DBP	81	79
Race		
Caucasian	488	561
African		
American	153	70
Asian	13	17
Latino	13	20
Native Am	1	3
Unreported	63	71
Sport intensity		
1	119	172
2	356	186
3	254	383

Sport intensity was defined as: 1 low intensity athletics: Cheerleading, Volleyball, Softball, Baseball; 2: intermediate intensity: Track, Field Hockey, Tennis, Football, Soccer; 3: high intensity: Swimming, lacrosse, Rowing.