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Electrocardiogram in Pre-Participation Athletic Evaluations Among Insured Youths

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Abstract

Objective—To retrospectively characterize electrocardiogram (ECG) use among pre-participation history and examinations (PPEs).

Study design—Using the 2005 to 2010 MarketScan® insurance database, we identified subjects aged 5 to 21 years with either a PPE with an ECG or a PPE alone, excluding those with known cardiac diagnoses. We described cardiology referrals and subspecialty testing within 180 days and cardiac diagnoses within 1 year of the PPE, and the costs of testing in each group.

Results—From 2005 to 2009, 503,304 PPEs occurred in 419,456 subjects, of which 8,621 (2%) included an ECG. ECG use increased from 12 to 20 per 1000 PPEs from 2005 to 2009. Females, lower socioeconomic status, and rural settings were associated with fewer ECGs. 13% of PPEs with ECG and 0.5% of PPEs alone led to a cardiology referral. After PPEs with ECG, cardiac disease was identified in 18% (2% sports-limiting); after PPEs alone, cardiac disease was identified in 0.5% (0.03% sports-limiting). The PPE had a sensitivity of 44% and a specificity of 98.6% of identifying cardiac disease. The total reimbursement cost of PPEs plus testing was \$80,396,464 (\$160 per PPE).

Conclusions—These real-world data demonstrate that community providers selectively use the ECG as part of the PPE with a high rate of identification of cardiac disease. Mass ECG screening would need to be more efficient at identifying disease than this selective approach.

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Keywords

Sudden Death; Pediatrics; Electrocardiogram Screening

Sudden cardiac death in young athletes is a rare but catastrophic event that propels families, providers, and communities to action to prevent such future tragedies. One prevention approach entails pre-participation screening of competitive athletes. An Italian program of pre-participation athletic screening that included an electrocardiogram (ECG) is purported to have reduced annual mortality by 89% over 25-years,^{1, 2} prompting some to advocate for adding an ECG to the pre-participation history and examination (PPE) screening in the United States (US).³ Experiences in other countries have not shown similar results.⁴ Proponents note that adding an ECG increases the yield for identifying diseases associated with sudden cardiac death,⁵ whereas critics of ECG screening highlight the differences between US and Italian demographics and disease distribution and note that the reduced mortality rate in Italy after implementation was comparable with the US death rate without systematic screening.^{6–8} Critics also cite the limitations of the ECG, with its high false positive rate and inability to detect some diseases associated with sudden death.⁹ The debate about the cost effectiveness of adding an ECG to the PPE involves variable assumptions and has produced conflicting results.^{10–12}

European and US guidelines differ in their recommendations of whether to use the ECG in the context of mass screening of athletes.^{13–16} The American Heart Association (AHA) and the American College of Cardiology (ACC) do not recommend the use of systematic ECG screening of US athletes due to a lack of resources and a high rate of false positive ECGs.^{15, 16}

Editorials,¹⁷ cost-effectiveness analyses,^{10, 11} and guidelines^{13, 15, 16} frame the ECG screening debate as a dichotomous decision: mass ECG screening versus PPE alone. Yet alternative strategies, such as selective use of the ECG, are rarely discussed. Therefore, the purpose of this study was to use a large insurance database to determine the frequency of ECG use as part of the PPE and to describe the subsequent medical testing, diagnostic yield, and associated costs.

Methods

Data were obtained retrospectively from The Truven Health Analytics MarketScan® Commercial Claims and Encounter Database. Created by the Medstat Group, Inc., this database contains insurance claims data on 49 million employees, spouses and dependents, ages 0 to 64 years, covered through large employers in various private health care plans. The geographical distribution roughly follows the US population distribution (39% of the sample is from the South, 21% from the West, 25% from the North Central region, and 15% from the Northeast). Data on race and ethnicity are not included. Information from inpatient and outpatient settings is integrated at the patient level, allowing for tracking of patients through the medical continuum. Complete payment information, including reimbursement, is captured, and patient- and provider-level data are de-identified to protect privacy. Clinical data, such as ECG and testing results, are not available in the database.¹⁸ Because this study

used de-identified data from an existing database, it was not considered human subjects research.

The sample included all outpatient encounters between 2005 and 2010 for more than 12.3 million subjects, 5 to 21 years of age. We identified subjects with an International Classification of Diseases, Ninth Edition (ICD-9) code for a PPE (medical examination for sports competition, V70.3) between 2005 and 2009. Subjects with a PPE in 2009 were followed into 2010 to allow time for referrals and testing. We excluded subjects with previous known diagnoses of arrhythmia (ICD-9 code: 426–427), valve disease (394–397, 424), congenital heart disease (CHD) (745–747), or cardiomyopathy (425).¹⁹

An ECG was considered to be part of the PPE if it occurred within 90 days after the PPE but before the cardiologist visit. In those with a PPE and an ECG, we calculated the time interval between the PPE and ECG. We analyzed temporal changes in the number of PPEs with ECG and identified factors associated with increased likelihood of undergoing a PPE with ECG. In the absence of clinical detail in the database, to understand possible indications for the ECG or cardiology referral, we identified PPEs that were coded with cardiac history or symptoms, including palpitations, murmur, chest pain, dyspnea, syncope, dizziness, and family history of sudden cardiac death or other cardiovascular diseases. We characterized how many PPEs led to a cardiology referral and additional testing within 180 days of the PPE, and cardiac diagnoses and therapeutic procedures within one year after the PPE. To calculate costs, we assessed reimbursements in 2012 dollars for PPEs and testing among those who were referred to a cardiologist. Therapeutic procedures were not included in the cost analysis. Data are presented at the level of the PPE unless specified otherwise.

An ECG was considered to be additional testing if it occurred on the day of the cardiologist visit. Additional testing was defined as a subsequent ECG, echocardiogram (echo), exercise stress test, Holter monitor, electrophysiology (EP) study, cardiac catheterization or cardiac magnetic resonance imaging (CMR) study following a cardiology visit. Therapeutic procedures included catheter ablation, placement of an implantable cardioverter-defibrillator, and coronary artery re-implantation.

We categorized cardiac diagnoses broadly by ICD-9 code as arrhythmia, valve disease, CHD, and cardiomyopathy. Based on their association with an increased risk of sudden cardiac death, we designated these specific cardiac diagnoses as sports-limiting: aortic/subaortic stenosis (ICD-9 code 746.3, 746.81, or 747.22), coronary artery anomalies (746.85), hypertrophic cardiomyopathy (HCM) (425.1), other cardiomyopathy (425.4), long QT syndrome (426.82), ventricular tachycardia (427.1), and Wolff-Parkinson-White syndrome (426.7).¹⁹

We calculated the sensitivity, specificity, and false positives of the PPE for identifying cardiac disease. For this calculation, we assumed that the act of ordering an ECG was in response to positive findings during the PPE. Therefore, the PPE was considered to be positive if the decision was made to obtain an ECG. A diagnosis of cardiac disease in the PPE with ECG group (regardless of whether the subject was referred to a cardiologist) was considered to be a true positive, and a cardiac diagnosis in the PPE alone group (regardless

of cardiology referral) was considered to be a false negative. We also calculated the number needed to screen (number screened/diagnoses made) for the PPE with ECG group and the PPE alone group.

Statistical Analyses

Descriptive statistics (frequencies, percentages, means, medians, and interquartile ranges) were used to characterize PPEs, ECGs, symptoms, testing, diagnoses, therapeutic procedures and costs and to calculate the sensitivity, specificity, false positives, and number needed to screen. Logistic regression multivariable modeling was used to determine the likelihood of undergoing an ECG with the PPE. The model included: age, year, sex, rural setting, region, and payer (fee for service, preferred provider organization, point of service, health maintenance organization, and high deductible plan). We also included in the model “parents with hourly wage” (as opposed to salaried positions) as a proxy for lower socioeconomic status. A p-value of <0.05 was deemed statistically significant. Analyses were performed using Stata 12.

Results

From 2005 to 2009, 503,304 PPEs were performed in 419,456 subjects, and 65,679 (16%) subjects had more than one PPE during the study period. The mean age was 14.3 ± 3.4 years, and 84% of subjects were 12 years of age. An ECG was associated with 8,621 (2%) PPEs. The median time between the PPE and ECG was 2 days (interquartile range: 0–38 days). ECG use increased from 12 to 20 per 1000 PPEs from 2005 to 2009 (Table I).

PPEs were more likely to be associated with an ECG if subjects were older or had a PPE more recently (Table II). A lower likelihood of undergoing a PPE with ECG was associated with female sex, lower socioeconomic status, rural setting, and North Central and West regions (compared with the Northeast). The South region was not statistically different from the Northeast in the rate of ECG use. Payer type was not associated with having a PPE with ECG.

The Figure (available at www.jpeds.com) demonstrates the downstream effects for subjects with a PPE with and without an ECG. Of the 8,621 PPEs with ECG, 1,081 (13%) led to a cardiologist referral, whereas 2,443 (0.5%) of the 494,683 PPEs alone resulted in referral. The prevalence of cardiac symptoms was low overall, yet it was higher among those who received an ECG with the PPE (4%) than those who underwent the PPE alone (0.1%). After cardiology referral, the prevalence of testing was high in both groups (88% PPE with ECG vs. 71% PPE alone), including an echo in more than half of the cardiology visits (Table III).

In our cohort of 419,456 subjects, the overall prevalence of cardiac disease was 0.8%, and the prevalence of sports-limiting cardiac diagnoses was 0.06%. Among subjects who underwent PPE with an ECG, cardiac disease was identified in 1,511 (18%) subjects within 1 year of the PPE. Of these, 143 (2% of subjects who underwent PPE with an ECG) had sports-limiting diagnoses. In the PPE alone group, cardiac disease was identified in 1,921 (0.5%) subjects within 1 year of the PPE. Of these, 122 (0.03% of subjects who underwent

PPE alone) had sports-limiting diagnoses. The distribution of cardiac diagnoses was similar across the groups.

Therapeutic procedures were performed in 17 subjects, 9 from the PPE with ECG group and 8 from the PPE alone group. Such procedures included 15 catheter ablations, one placement of an implantable cardioverter-defibrillator, and one coronary artery re-implantation.

Of the 65,679 subjects with more than one PPE during the study period, 1,023 (2%) had an ECG with the first PPE and 64,656 (98%) had a PPE alone at the first visit. Of subjects who received a cardiac diagnosis, 90% received that diagnosis after the first PPE (44% of these subjects had an ECG during the first PPE).

The sensitivity of the PPE for identifying cardiac disease was 44%; the specificity was 98.6% with a false positive rate of 1.4%. The number needed to screen for the PPE with ECG was 5.5, whereas the number needed to screen for the PPE alone was 244.

In 2012 dollars, the total reimbursement cost of PPEs plus downstream testing for those who were referred to a cardiologist was \$80,396,464 or \$160 per PPE. This cost represents a lower bound of costs, as the costs of additional testing for those who did not see a cardiologist, of therapeutic procedures and of additional testing occurring more than 180 days after the PPE were not included in the analysis.

Discussion

Using a large insurance database, we demonstrate two key findings: (1) providers performing PPEs are employing the selective use of the ECG as part of the PPE; and (2) the community-level use of the ECG as part of the PPE among insured youths has increased from 2005 to 2009.

Editorials, guidelines and cost-effectiveness analyses have typically framed the debate over ECG screening to be a choice between mass ECG screening or PPE alone; alternative strategies are rarely discussed. In the cost-effectiveness analysis performed by Schoenbaum et al, the authors compare three screening strategies: PPE alone versus PPE with mass ECG screening versus ECG alone.¹⁰ Wheeler et al. also evaluated various screening strategies, including no screening, PPE alone, and PPE with ECG.¹¹ But neither study considers the selective use of the ECG. Roberts et al suggest that using the ECG selectively as a “case finding tool” rather than screening all athletes with an ECG will increase the likelihood that the positive ECG test will represent a true positive. They indicate that the selective approach, as we describe in our analysis, will cause less harm to the population by decreasing the numbers of athletes who are unnecessarily restricted or delayed by false positive results.²⁰

Two percent of PPEs in our large sample had an associated ECG. The limited clinical detail in this administrative insurance database prevents knowing with certainty why providers ordered an ECG as part of the PPE. However, the rate of symptoms coded at the time of the PPE, while low overall, was higher in those with PPE and ECG, suggesting an increased level of suspicion of cardiac disease in that group. We acknowledge that all symptoms

disclosed may not be reflected in the codes assigned to that visit. Nonetheless, the high diagnosis rate in the PPE with ECG group, as indicated by the low number needed to screen, may indicate that the decision by the provider to obtain an ECG was prompted by concerning history or physical examination findings. This data suggests that providers may be appropriately implementing the AHA/ACC-recommended approach of PPE with selective initiation of evaluation (with an ECG at a minimum and a cardiologist referral in some) in patients with concerning findings. This approach led to the identification of a high percentage of subjects with true disease.

Among subjects with multiple PPEs during the study period, our data demonstrate that the yield of the first PPE was high; 90% of subjects with a cardiac diagnosis received that diagnosis after the first PPE. Although cases of HCM that progress during puberty may be more identifiable on subsequent PPEs, the high rate of diagnosis at the first PPE is a reassuring finding. These may inform the discussions about the frequency of screening, as the European guidelines¹³ currently recommend screening every 2 years, whereas the US guidelines¹⁶ do not include recommendations about repeat screening.

Previous cost-effectiveness analyses have used the PPE alone as a baseline comparator.^{10, 11} For future cost-effectiveness analyses, selective ECG use, as depicted by this real-world data, may be a more appropriate baseline comparator.

Increasing use of the ECG as part of the PPE during the study period may reflect community-level exposure to abundant media coverage of events of sudden cardiac death and awareness of the ECG screening debate. The European Society of Cardiology and the International Olympic Committee endorsements of ECG screening and the Italian experience were published in 2005 and 2006. In March of 2007, the AHA/ACC did not recommend ECG as part of a large-scale national screening program for US competitive athletes, but suggested that it was not unreasonable to conduct such screening locally.^{1, 13–15} We noted an increase of PPEs and PPEs with ECG beginning in 2007, suggesting an awareness of the recommendations and perhaps reflecting provider preferences in response to the controversy.

We also noted that older subjects were more likely to have a PPE with ECG. This may indicate an increased likelihood of adolescents participating in higher intensity activities and increased ECG use during the pre-participation evaluation of high school athletes, the largest age group participating in organized competitive sports in the US. This is likely prompted by the reported increased risk of sudden cardiac arrest during sports in susceptible patients with underlying heart disease,^{1, 21, 22} as well as significant media attention that is generated by the sudden death of an athlete.

The decreased likelihood of receiving a PPE with ECG among females in our study may indicate a lower level of concern due to the lower risk of sudden cardiac death noted among female athletes in previous studies.^{16, 22, 23} The lower likelihood of PPE with ECG among those with lower socioeconomic status, in rural settings, and in the North Central and West regions has not been described. Such regional and economic differences may suggest variable access to ECGs, a topic that merits further study.

The 2007 AHA/ACC Scientific Statement estimated the prevalence of conditions associated with sudden cardiac death in the general athlete population to be 0.3%.¹⁵ Our real-world cohort revealed a lower prevalence (0.06%), reflecting possible ascertainment bias in this large, but not nationally representative, insurance database as well as possible under-detection of cardiac disease. Our cohort had a low rate of HCM, consistent with Malhotra's ECG screening program of US college athletes that did not reveal any HCM.²⁴

In the Italian experience, 2% of athletes were disqualified due to a cardiac diagnosis.¹ In a feasibility study of 400 subjects 5 to 19 years of age screened with PPE with ECG and echo, Vetter identified potentially serious cardiac disease in 2.5%.²⁵ Baggish recommended sports restriction in 0.6% of 510 college athletes screened with PPE, ECG, and echo.²⁶ Our rate of sports-limiting diagnoses from PPEs with ECG (2%) was similar to Corrado and Vetter, but higher than Baggish. Baggish's lower rate may be due to examination of a highly selective group of athletes that may have a lower incidence of latent disease influenced by previous restriction of those with established cardiac disease. Conversely, our rate of sports-limiting diagnoses may reflect a higher pre-test probability of disease in the enriched PPE with ECG group. However, our database does not provide enough clinical detail to ascertain whether patients with sports-limiting diagnoses in our study were, in fact, disqualified from athletics.

Our study should be interpreted in light of its limitations. The database is a convenience sample from large employers and is subject to sample bias. It does not include patients who are uninsured or on Medicaid, or those whose parents are unemployed or work at smaller companies; nor does it capture individuals evaluated by school-based PPEs. Young black males have higher rates of ECG abnormalities and undetected HCM,²⁷ the lack of data on race in this database means that we cannot evaluate whether their proportion in this cohort is representative of the general population.

As with all databases, this study is subject to imprecise coding and errors, although the large sample size may mitigate this to an extent. Our data also are limited to 2005 to 2010, and identification of cardiac disease was restricted to one year after the PPE. Without long-term data, we are unable to determine the number of true negatives and if the false negative cases eventually developed cardiac disease, which may impact the calculation of specificity and false positive rate. To be captured, additional testing needed to be completed within 180 days of the PPE; therefore the number of additional studies and associated costs may also be underestimated in our analysis.

The lack of clinical detail in the database limits our ability to understand the results of testing, the indications for the ECG, cardiologist referral, additional testing, and therapeutic procedures. Although the median time between PPE and ECG was short, we cannot be certain that the ECG was prompted by the PPE in all cases. Moreover, without additional information, we cannot explain why, of those who were referred to a cardiologist after a PPE alone, only 23% received an ECG. Likewise, the lack of clinical detail limited our understanding of the diagnosis of cardiac disease among those who did not have a cardiologist referral. It is possible that these subjects developed symptoms throughout the year that prompted an emergency department visit or hospital admission that resulted in a cardiac diagnosis; however this level of clinical detail is not available. It is also possible that

the cardiologist visit in these patients occurred more than 180 days after the PPE and was not captured in our analysis.

Finally, cost figures may be underestimated in both groups because the costs of additional testing were not included for patients who did not see a cardiologist, and the costs of additional testing occurring more than 180 days after the PPE, and therapeutic procedures were not included in the analysis. Nevertheless, this study takes advantages of one of the strengths of administrative databases, that is, evaluating real-world practice patterns in large numbers of patients.

The current debate over ECG screening for athletes typically compares mass ECG screening to PPE alone. Our data characterize the approach that is being employed in the community, the selective use of the ECG in concerning cases, an approach that results in a high rate of identification of subjects with true cardiac disease. Adoption of a mass ECG screening program in the US would therefore need to prove to be more efficient at identifying diseases associated with sudden cardiac death than this current selective approach.

Abbreviations

ACC	American College of Cardiology
AHA	American Heart Association
CHD	congenital heart disease
echo	echocardiogram
ECG	electrocardiogram
EP	electrophysiology
HCM	hypertrophic cardiomyopathy
ICD-9	International Classification of Diseases, Ninth Edition
CMR	cardiac magnetic resonance imaging
PPE	pre-participation history and examination
US	United States

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Figure.

Downstream effects of PPE with and without an ECG. It quantifies PPEs and subjects, associated coded symptoms at the time of PPE, subsequent cardiologist referrals and testing within 180 days of the PPE, and cardiac and sports-limiting cardiac diagnoses within 1 year of the PPE. Some subjects had more than one diagnosis.

Table 1

Temporal Frequencies of PPE and PPE with ECG

Year	PPE (n)	PPE + ECG (n)	PPE + ECG (per 1,000 examinees)
2005	56,591	703	12
2006	61,475	864	14
2007	122,713	1,858	15
2008	113,894	2,153	19
2009	148,631	3,043	20
Total	503,304	8,621	17

Table 2

Multivariable Model for the Likelihood of Having a PPE with ECG

Variable (n=503,304)	Odds Ratio (95% Confidence Interval)	p-value
Age:		
5 – 13 years	<i>Reference</i>	
14 – 16 years	1.63 (1.54 – 1.72)	<0.001
17 – 21 years	1.79 (1.68 – 1.90)	<0.001
Year:		
2005	<i>Reference</i>	
2006	1.16 (1.05 – 1.29)	0.005
2007	1.21 (1.11 – 1.33)	<0.001
2008	1.51 (1.38 – 1.65)	<0.001
2009	1.67 (1.53 – 1.82)	<0.001
Female:	0.87 (0.83 – 0.91)	<0.001
Lower Socioeconomic Status:	0.87 (0.80 – 0.94)	0.001
Rural Setting:	0.63 (0.60 – 0.67)	<0.001
Region:		
Northeast	<i>Reference</i>	
North Central	0.64 (0.59 – 0.70)	<0.001
West	0.70 (0.63 – 0.77)	<0.001
South	1.08 (0.99 – 1.17)	0.082
Payer:		
Fee For Service	<i>Reference</i>	
Preferred Provider Organization	0.98 (0.83 – 1.14)	0.763
Point of Service	1.01 (0.85 – 1.20)	0.906
Health Maintenance Organization	0.88 (0.74 – 1.04)	0.138
High Deductible Plan	0.83 (0.67 – 1.02)	0.080

Table 3

Cardiology Visits with Additional Testing

	PPE with ECG n (%)	PPE Alone n (%)
Total Cardiologist Visits with No Additional Testing	135 (12)	711 (29)
Total Cardiologist Visits with Additional Testing*	946 (88)	1,732 (71)
Additional Testing		
Echo	629 (58)	1,279 (52)
ECG [†]	493 (46)	549 (23)
Stress Test	192 (18)	160 (7)
Holter	122 (11)	123 (5)
CMR	6 (0.6)	5 (0.2)
EP Study	19 (2)	3 (0.12)
Cardiac Catheterization	0	1 (0.04)

* Some visits resulted in multiple additional tests.

[†] This refers to an additional ECG at the cardiology visit; not to the ECG associated with the PPE