Editorial

Training and Experience Matter

Improving Athlete ECG Screening, Interpretation, and Reproducibility

Jordan M. Prutkin, MD, MHS; Jonathan A. Drezner, MD

A preparticipation evaluation is recommended before engaging in competitive sports, although debate continues whether to include an ECG in addition to a history and physical examination. The limitations of preparticipation screening by history and physical examination alone for the identification of athletes with disorders at risk for sudden cardiac arrest have been recognized by 2 recent consensus statements within the United States.[1,2] ECG screening of young athletes is endorsed by several major medical and sporting organizations, such as the European Society of Cardiology (ESC), International Olympic Committee, and Fédération Internationale de Football Association, as a means to improve the identification of conditions predisposing to sudden cardiac arrest. However, accurate implementation of an ECG screening program has many challenges and requires a physician infrastructure with adequate sports cardiology resources and training in contemporary athlete-specific ECG interpretation standards.

See Article by Dhutia et al

In this issue, Dhutia et al[3] examined the reproducibility of ECG interpretation using the 2010 ESC, 2013 Seattle Criteria, and 2014 Refined Criteria by 4 experienced and 4 nonexperienced cardiologists in 400 athletes. The study also analyzed the downstream costs of further testing depending on the experience level of the reader. Not surprisingly, the study found that interobserver reliability was better with experienced versus novice readers and improved for both groups with the newer criteria. This was a small sample, and no follow-up was available so it is unknown if any athlete in this cohort had true disease.

Evolution of ECG Interpretation Standards

Physiological changes in the athlete's heart have made determination of normal ECG findings in the athlete a challenge. The 2010 criteria endorsed by the ESC[4] represented the first attempt to acknowledge physiological ECG changes related to regular exercise and created 2 groups of ECG findings: group 1 (normal and training related) and group 2 (abnormal and training unrelated). The biggest weakness of these criteria was a high false-positive rate, especially in blacks.[5]

Other athlete-specific ECG criteria emerged but were not widely used until the 2013 Seattle Criteria.[6] The goal of this document was to reduce the false-positive rate while still maintaining the sensitivity to detect conditions at risk for sudden cardiac arrest. The Seattle Criteria led to an increase in the use of athlete-specific ECG interpretation standards, but new studies suggested that specificity could be further improved. Sheikh et al[5] created the Refined Criteria which, for the first time, included a borderline category whose findings were considered normal if seen alone, but required further evaluation if ≥2 findings were present.

As the newer criteria were developed, one of the major changes was a modification in the QT interval cutoff value that required additional evaluation (from a QTc >440 ms in males and >460 ms in females to a QTc ≥470 ms in males and ≥480 ms in females). Dutia et al[3] showed, however, the continued difficulty in determining whether QT intervals are greater than these values even with higher cutoffs. In addition, identification of pathological Q waves and ST depression had poor agreement regardless of experience level. This may be influenced by the difficulty adjudicating whether an ST segment is ≥0.5 mm deep or a Q wave is ≥40 ms in duration or ≥25% the height of the R wave, which can be very fine values to determine at standard paper speed and gain. In addition, the lack of a computer-generated number to guide decision making may have made it more difficult to determine the depth and duration of values.

Several studies have compared the 3 criteria recommendations for ECG interpretation in athletes (Table).[3,5,7–10] With each evolution of ECG standards, the specificity has improved without any significant loss in sensitivity. In the current study, Dhutia et al[3] found a particularly high ECG positive rate using the ESC criteria even though there was a lower proportion of black athletes, a group whom the criteria are not thought to be as accurate.[5] This study also included a slightly older population which may have allowed more time for phenotypic changes to occur.

Experience Matters

In this study, the cost per athlete screened for inexperienced cardiologists was $175 USD (95% confidence interval, $142–$228) and for experienced cardiologists was $101 USD (95% confidence interval, $83–$131). In a different cohort of 4295 athletes, these authors have previously shown a lower

The opinions expressed in this editorial are not necessarily those of the editors or of the American Heart Association.

From the Division of Cardiology (J.M.P.) and Department of Family Medicine (J.A.D.), University of Washington, Seattle.

Correspondence to Jonathan A. Drezner, MD, Department of Family Medicine, Center for Sports Cardiology, University of Washington, Seattle, WA 98195. E-mail jdrezner@uw.edu

(*Circ Cardiovasc Qual Outcomes.* 2017;10:e003881. DOI: 10.1161/CIRCOUTCOMES.117.003881.)

***Circ Cardiovasc Qual Outcomes* is available at http://circoutcomes.ahajournals.org**

DOI: 10.1161/CIRCOUTCOMES.117.003881

Table. Studies Examining the Total Positive Rate of Abnormal ECGs Using the European Society of Cardiology, Seattle Criteria, and Refined Criteria

Study	European Society of Cardiology[4]	Seattle Criteria[6]	Refined Criteria[5]
Dhutia et al[3] 2017; inexperienced	39.0%	16.1%	7.2%
Dhutia et al[3] 2017; experienced	31.3%	8.0%	5.5%
Dhutia et al[7] 2016	21.8%	6.0%	4.3%
Fuller et al[8] 2016	10.7%	2.8%	2.8%
Sheikh et al[5] 2014	21.5%	9.6%	6.6%
Riding et al[9] 2015	22.3%	11.6%	5.3%
Brosnan et al[10] 2014	17.0%	4.2%	…

rate of ECG abnormalities and costs of $110 USD per athlete screened for the ESC criteria, $92 USD for the Seattle Criteria, and $87 USD for the Refined Criteria.[7] The current study adds valuable insights as to how these costs may vary based on who is doing the ECG reading and athlete evaluation.

Malhotra et al[11] examined the cost of screening in the United States using the ESC criteria. Although they did not directly report costs per athlete screened, extrapolating from their data shows it was $607 USD. The cost is greater largely because of the higher number of athletes getting secondary testing for ECG findings no longer considered abnormal (ie, isolated voltage criteria for left ventricular hypertrophy and any T-wave inversion in V_1, V_2, or V_3). In addition, costs are substantially higher in the United States. In the Malhotra et al[11] study, the cost of an echocardiogram was $900 USD in 2011 compared with the $112 USD in the current study by Dhutia et al.[3] It is important to recognize, therefore, that the cost estimates in the current study may be gross underestimations of true costs in the United States.

Other factors may also influence costs, such as the proportion of each abnormality seen as the extent of secondary evaluation is different. In our experience, Wolff–Parkinson–White pattern is the most common ECG abnormality,[12] although none was seen in this study.

Moving Forward

As this study was completed, the new International Recommendations for ECG Interpretation in Athletes were published.[13] This expert consensus statement was designed as an update to the Seattle Criteria and the Refined Criteria. Endorsed by 17 international sports medicine and cardiology societies, this guideline likely will emerge as the standard of care for ECG interpretation in athletes. Key changes compared with the Seattle Criteria include recognition of juvenile T-wave inversion as a normal finding, a new definition for pathological Q waves, recommended secondary testing for single lead T-wave inversion in V_5 or V_6, and the addition of a borderline category for right bundle branch block, axis deviation, and atrial enlargement in which ≥2 findings are needed to trigger more evaluation. The international criteria also include recommendations for the initial workup for specific ECG abnormalities. The potential benefit of this link between specific ECG abnormalities and the recommended secondary testing is to reduce diagnostic variability among providers.

We have shown that education on athlete ECG criteria can improve interpretation accuracy regardless of medical specialty and training level.[14] Enhanced education will improve the reproducibility and accuracy of ECG interpretation. In addition, there should be ongoing efforts to conduct ECG interpretation in athletes in clinical practice to maintain and sharpen skills. ECG interpretation is complex, and it is not enough to do a single screening once a year. Like other medical skills, it must be done repeatedly so proficiency is enhanced.

As this study shows, the bias in ECG interpretation is to overcall abnormalities to be safe. Recognizing physiological findings is a critical step to minimize false-positive rates and the costs of unnecessary secondary testing. Fortunately, each revision of athlete ECG standards has improved specificity, and the international criteria should be no exception. A greater focus on physician education, training, and practical experience should continue to improve the accuracy and reproducibility of ECG screening in athletes.

Disclosures

None.

References

1. Drezner JA, O'Connor FG, Harmon KG, Fields KB, Asplund CA, Asif IM, Price DE, Dimeff RJ, Bernhardt DT, Roberts WO. AMSSM position statement on cardiovascular preparticipation screening in athletes: current evidence, knowledge gaps, recommendations and future directions. *Br J Sports Med*. 2017;51:153–167. doi: 10.1097/JSM.0000000000000382.
2. Hainline B, Drezner JA, Baggish A, Harmon KG, Emery MS, Myerburg RJ, Sanchez E, Molossi S, Parsons JT, Thompson PD. Interassociation consensus statement on cardiovascular care of college student-athletes. *J Am Coll Cardiol*. 2016;67:2981–2995. doi: 10.1016/j.jacc.2016.03.527.
3. Dhutia H, Malhotra A, Yeo TJ, Ster IC, Gabus V, Steriotis A, Dores H, Mellor G, Garcia-Corrales C, Ensam B, Jayalapan V, Ezzat VA, Finocchiaro G, Gati S, Papadakis M, Tome M, Sharma S. Inter-rater reliability and downstream financial implications of electrocardiography screening in young athletes. *Circ Cardiovasc Qual Outcomes*. 2017;10:e003306. doi: 10.1161/CIRCOUTCOMES.116.003306.
4. Corrado D, Pelliccia A, Heidbuchel H, Sharma S, Link M, Basso C, Biffi A, Buja G, Delise P, Gussac I, Anastasakis A, Borjesson M, Bjørnstad HH, Carrè F, Deligiannis A, Dugmore D, Fagard R, Hoogsteen J, Mellwig KP, Panhuyzen-Goedkoop N, Solberg E, Vanhees L, Drezner J, Estes NA III, Iliceto S, Maron BJ, Peidro R, Schwartz PJ, Stein R, Thiene G, Zeppilli P, McKenna WJ; Section of Sports Cardiology, European Association of Cardiovascular Prevention and Rehabilitation. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. *Eur Heart J*. 2010;31:243–259. doi: 10.1093/eurheartj/ehp473.
5. Sheikh N, Papadakis M, Ghani S, Zaidi A, Gati S, Adami PE, Carré F, Schnell F, Wilson M, Avila P, McKenna W, Sharma S. Comparison of electrocardiographic criteria for the detection of cardiac abnormalities in elite black and white athletes. *Circulation*. 2014;129:1637–1649. doi: 10.1161/CIRCULATIONAHA.113.006179.
6. Drezner JA, Ackerman MJ, Anderson J, Ashley E, Asplund CA, Baggish AL, Börjesson M, Cannon BC, Corrado D, DiFiori JP, Fischbach P, Froelicher V, Harmon KG, Heidbuchel H, Marek J, Owens DS, Paul S, Pelliccia A, Prutkin JM, Salerno JC, Schmied CM, Sharma S, Stein R, Vetter VL, Wilson MG. Electrocardiographic interpretation in athletes: the 'Seattle criteria'. *Br J Sports Med*. 2013;47:122–124. doi: 10.1136/bjsports-2012-092067.
7. Dhutia H, Malhotra A, Gabus V, Merghani A, Finocchiaro G, Millar L, Narain R, Papadakis M, Naci H, Tome M, Sharma S. Cost implications of using different ECG criteria for screening young athletes in the United Kingdom. *J Am Coll Cardiol*. 2016;68:702–711. doi: 10.1016/j.jacc.2016.05.076.
8. Fuller C, Scott C, Hug-English C, Yang W, Pasternak A. Five-year experience with screening electrocardiograms in National Collegiate Athletic

Association Division I Athletes. *Clin J Sport Med*. 2016;26:369–375. doi: 10.1097/JSM.0000000000000318.
9. Riding NR, Sheikh N, Adamuz C, Watt V, Farooq A, Whyte GP, George KP, Drezner JA, Sharma S, Wilson MG. Comparison of three current sets of electrocardiographic interpretation criteria for use in screening athletes. *Heart*. 2015;101:384–390. doi: 10.1136/heartjnl-2014-306437.
10. Brosnan M, La Gerche A, Kalman J, Lo W, Fallon K, MacIsaac A, Prior D. The Seattle Criteria increase the specificity of preparticipation ECG screening among elite athletes. *Br J Sports Med*. 2014;48:1144–1150. doi: 10.1136/bjsports-2013-092420.
11. Malhotra R, West JJ, Dent J, Luna M, Kramer CM, Mounsey JP, Battle R, Saliba E, Rose B, Mistry D, MacKnight J, DiMarco JP, Mahapatra S. Cost and yield of adding electrocardiography to history and physical in screening Division I intercollegiate athletes: a 5-year experience. *Heart Rhythm*. 2011;8:721–727. doi: 10.1016/j.hrthm.2010.12.024.
12. Drezner JA, Owens DS, Prutkin JM, Salerno JC, Harmon KG, Prosise S, Clark A, Asif IM. Electrocardiographic screening in National Collegiate Athletic Association Athletes. *Am J Cardiol*. 2016;118:754–759. doi: 10.1016/j.amjcard.2016.06.004.
13. Sharma S, Drezner JA, Baggish A, Papadakis M, Wilson MG, Prutkin JM, La Gerche A, Ackerman MJ, Borjesson M, Salerno JC, Asif IM, Owens DS, Chung EH, Emery MS, Froelicher VF, Heidbuchel H, Adamuz C, Asplund CA, Cohen G, Harmon KG, Marek JC, Molossi S, Niebauer J, Pelto HF, Perez MV, Riding NR, Saarel T, Schmied CM, Shipon DM, Stein R, Vetter VL, Pelliccia A, Corrado D. International recommendations for electrocardiographic interpretation in athletes. *J Am Coll Cardiol*. 2017;69:1057–1075. doi: 10.1016/j.jacc.2017.01.015.
14. Drezner JA, Asif IM, Owens DS, Prutkin JM, Salerno JC, Fean R, Rao AL, Stout K, Harmon KG. Accuracy of ECG interpretation in competitive athletes: the impact of using standardised ECG criteria. *Br J Sports Med*. 2012;46:335–340. doi: 10.1136/bjsports-2012-090612.

Key Words: Editorials ■ athletes ■ cardiologists ■ reading ■ sports

Circulation
Cardiovascular Quality and Outcomes

Training and Experience Matter: Improving Athlete ECG Screening, Interpretation, and Reproducibility

Jordan M. Prutkin and Jonathan A. Drezner

Circ Cardiovasc Qual Outcomes. 2017;10:e003881
doi: 10.1161/CIRCOUTCOMES.117.003881
Circulation: Cardiovascular Quality and Outcomes is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 1941-7705. Online ISSN: 1941-7713