**The Impact of the International Recommendations for Electrocardiographic Interpretation on Cardiovascular Screening in Young Athletes**

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Abbreviations

ECG: Electrocardiography

ESC: European Society of Cardiology

MRI: Magnetic Resonance Imaging

UK: United Kingdom

**LETTER**

Pre-participation cardiovascular screening of young athletes with ECG is practiced by several major sporting organisations. A primary argument against this practice is the workload and cost associated with secondary investigations due to the high number of abnormal ECGs. We have previously shown that ECG screening with the contemporary Seattle and refined criteria is associated with significant savings [1].

Since our original report, the international recommendations for ECG interpretation in athletes have been published to assist clinicians in distinguishing physiological adaptations in athletes from distinctly abnormal findings suggestive of underlying pathology [2]. These consensus guidelines have yet to be validated in independent athlete cohorts. Therefore we investigated the performance of the international recommendations on our cohort of young athletes. .

Between 2011 and 2014, 4,925 previously unscreened athletes (85% male, 85% white) aged 14-35 years from 26 different sporting disciplines were prospectively evaluated by cardiologists with a health questionnaire pertaining to personal and family history, physical examination and a 12-lead ECG which was interpreted originally in accordance with the 2010 ESC recommendations. The evaluations were a mandatory requirement of their respective sporting association, and were facilitated nationwide through the Cardiac Risk in the Young screening program in the UK (www-c-r-y.org). Athletes with positive screening evaluations were referred to hospitals in their geographical vicinity for secondary investigations to confirm or refute the diagnosis of cardiac disease. Data relating to secondary investigations and the final diagnosis was obtained through communication with the club doctor using a questionnaire over 30 (6-54) months. The costs of secondary investigations were calculated based on the 2014/2015 UK National Health Service tariffs [1]. The impact on cost after applying the international recommendations was evaluated retrospectively.

Proportions are presented as percentages and 95% confidence intervals. Group differences of proportions were tested with the chi-square test. Ethical approval was granted by the Essex 2 Research Ethics Committee.

Seventy-nine (1.6% 95% CI 1.3%-2.0%) athletes had an abnormal health questionnaire or physical examination. Application of the international recommendations would result in 146 (3.0% 95% CI 2.5%-3.5%) athletes being classified as having a positive ECG, which represents an 86%, 50%, and 30% relative reduction compared to the 2010 ESC, Seattle and refined criteria respectively (all p<0.0001) (Figure 1A).

Inclusion of the ECG reported in accordance with the international recommendations to history and physical examination would result in 3.8% (95% CI 3.3%-4.1%) of the cohort undergoing transthoracic echocardiography, 1.2% (95% CI 0.9%-1.5%) exercise stress testing, 1.0% (95% CI 0.8%-1.1%), Holter, 0.9% (95% CI 0.7%-1.2%) cardiac MRI and 0.4% (95% CI 0.3%-0.7%) other tests respectively to confirm or refute a diagnosis of cardiac disease. The figures equate to a 66% reduction in the number of echocardiograms, 29% reduction in the number of exercise stress tests, 17% reduction in Holters, and 25% reduction in the number of cardiac MRI scans compared with the 2010 ESC recommendations (all p<0.0001) (Figure 1B). Fifteen (0.3% 95% CI 0.2%-0.5%) athletes were diagnosed with serious cardiac conditions (hypertrophic cardiomyopathy n=6, long QT syndrome n=3, Wolff-Parkinson-White syndrome ECG pattern n=6) after secondary investigation following an abnormal ECG according to all four ECG criteria.

The overall cost of screening using the 2010 ESC recommendations was $110 (95% CI $102-$122) per athlete and $35,993 (95% CI $33,474-$39,896) per serious diagnosis. The Seattle and refined criteria reduced the cost to $92 (95% CI $84-$103) and $87 (95% CI $80-$94) per athlete screened and $30,251 (95% CI $ 27,568-$ 33,912) and $28,510 (95% CI $ 26,329- $32,123) per serious diagnosis respectively. The international recommendations would further reduce cost to $80 (95% CI $74-91) per athlete and $26,405 (95% CI $24,392-$ 29,833) per serious diagnosis, representing a 27%, 13% and 8% relative cost reduction compared to the 2010 ESC, Seattle and refined criteria respectively.

The study is limited because we could not calculate the sensitivity or specificity of the international recommendations to detect disease as secondary investigation was limited to athletes with positive screening evaluations. Additionally, secondary investigations were performed at the discretion of attending cardiologists at the local hospitals and probably varied according to personal practice.

The international recommendations are associated with a significantly lower number of abnormal ECGs and result in an impressive reduction in workload and cost of screening without compromising the ability to detect athletes with serious cardiac disease Prospective evaluation is required to understand the actual impact of this consensus document on testing, cost and outcomes.

**REFERENCES**

1. Dhutia H,Malhotra A,Gabus V et al. Cost Implications of Using Different ECG Criteria for Screening Young Athletes in the United Kingdom. J Am Coll Cardiol.2016;68:702-711.
2. Sharma S,Drezner JA,Baggish A et al. International Recommendations for Electrocardiographic Interpretation in Athletes. J Am Coll Cardiol.2017;69:1057-1075.

**FIGURE LEGENDS**

Title: ECG abnormalities and secondary investigations following pre-participation screening.

Caption: Comparison of ECG abnormalities (1A) and secondary investigations (1B) following ECG screening with the 4 ECG interpretation criteria.

Key: Echo=Echocardiography, EST=Exercise stress test