Journal of the American College of Cardiology
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Published by Elsevier Inc.

Vol. 63, No. 19, 2014
ISSN 0735-1097/$36.00
http://dx.doi.org/10.1016/j.jacc.2014.01.046

Pediatric Cardiology

Prevalence of Electrocardiographic Anomalies in Young Individuals

Relevance to a Nationwide Cardiac Screening Program

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Objectives This study sought to investigate the prevalence of potentially abnormal electrocardiographic (ECG) patterns in young individuals to assess the implications for a nationwide screening program for conditions causing sudden cardiac death (SCD).

Background The Italian experience suggests that pre-participation screening with ECG reduces the incidence of SCD in athletes. However, the majority of SCDs occur in nonathletes. In the United Kingdom, screening for cardiac disorders is confined to symptomatic individuals or those with a family history of inherited cardiac conditions or premature cardiac death.

Methods Between 2008 and 2012, 7,764 nonathletes ages 14 to 35 years underwent ECG screening. Electrocardiograms were analyzed for group 1 (training-related) and group 2 (potentially pathological) patterns presented in the 2010 European Society of Cardiology position paper, which advocates further evaluation for individuals with group 2 ECG patterns. Results were compared with 4,081 athletes.

Results Group 1 patterns occurred in 49.1% of nonathletes and 87.4% of athletes ($p < 0.001$). Group 2 patterns occurred in 21.8% of nonathletes and 33% of athletes ($p < 0.001$). In nonathletes, QTc interval abnormalities comprised the majority (52%) of group 2 changes, whereas T-wave inversions constituted 11%. Male sex and African/Afro-Caribbean ethnicity demonstrated the strongest association with group 2 ECG patterns.

Conclusions The study demonstrates that 1 in 5 young people have group 2 ECG patterns. The low incidence of SCD in young people suggests that in most instances such patterns are non-specific. These findings have significant implications on the feasibility and cost-effectiveness of nationwide screening programs for cardiovascular disease in young nonathletes and athletes alike, on the basis of current guidelines. (J Am Coll Cardiol 2014;63:2028–34)

Most cardiac diseases predisposing to sudden cardiac death (SCD) in the young (age ≤35 years) are identifiable during life, and the risk of fatality may be minimized through the use of a range of therapeutic strategies (1). There are supportive data that electrocardiographic (ECG) screening identifies athletes who are harboring potentially serious cardiac diseases. There is also evidence that early identification and medical intervention reduces the incidence of SCD in competitive athletes (2). On the basis of this premise, ECG screening in athletes is endorsed by learned scientific and sporting organizations (3,4). To aid interpretation of the ECG in athletes, the European Society of Cardiology (ESC) has produced guidelines differentiating normal training-related ECG patterns (group 1) from ECG patterns suggestive of underlying heart disease (group 2), which should prompt investigation (Table 1) (3,5).

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Although intense exercise in individuals harboring quiescent cardiac pathology infers a 3-fold greater risk of SCD in elite athletes compared with nonathletes, the majority of SCD in the young affect the general population (6).

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Manuscript received September 25, 2013; revised manuscript received January 3, 2014, accepted January 6, 2014.

In most countries, young individuals are not offered cardiac screening unless they are engaged in competition at the highest level, express cardiac symptoms, and/or have a family history of premature cardiac disease (7). Moreover, attempts to institute general population screening are hampered by a paucity of data relating to the prevalence and significance of ECG changes in nonathletes.

This study aimed to establish the prevalence of group 2 ECG patterns in a large cohort of young individuals to evaluate the potential implications for a nationwide screening program in the general population.

Methods

Setting. The United Kingdom does not support a national, state-sponsored cardiac screening program. Many sporting organizations recommend pre-participation screening (PPS) and self-fund the evaluation of athletes competing at regional, national, or international levels. The charity Cardiac Risk in the Young (CRY) provides subsidized screening for conditions predisposing to SCD in individuals ages 14–35 years in the United Kingdom who wish to be tested for self-protection, irrespective of athletic status, symptoms, or family history of premature cardiac disease. Screening events are advertised in local media and on the CRY website. Individuals from the general population, including those from local high schools, self-present to screening events. Elite athletes attend specified screening events as part of PPS endorsed by their relevant sporting bodies. The senior author (S.S.) supervised the evaluations.

Subjects. Between 2008 and 2012, 11,845 consecutive individuals ages 14 to 35 years (7,764 nonathletes and 4,081 athletes) underwent evaluation comprising a health questionnaire and 12-lead ECG. A transthoracic echocardiogram was performed in individuals with group 2 ECG patterns suggestive of cardiomyopathy or structural cardiac abnormality.

Table 1 European Society of Cardiology Classification of Changes of the Athlete's Electrocardiogram

Group 1: Common and Training-Related ECG Changes	Group 2: Uncommon and Training-Unrelated ECG Changes
Sinus bradycardia	T-wave inversion
First-degree AV block	ST-segment depression
Incomplete RBBB	Pathological Q-waves
ER	LA enlargement
Isolated QRS voltage criteria for LVH	RA enlargement
	LAD
	RAD
	RVH
	Ventricular pre-excitation
	LBBB
	RBBB
	Long-QTc interval (>440 ms, men; >460 ms, women)
	Short-QTc interval (<380 ms)
	Brugada-like ER

Data from Corrado et al. (5).

AV = atrioventricular; ECG = 12-lead electrocardiogram; ER = early repolarization; LA = left atrial; LAD = left-axis deviation; LBBB = left bundle-branch block; LVH = left ventricular hypertrophy; RA = right atrial; RAD = right-axis deviation; RBBB = right bundle-branch block; RVH = right ventricular hypertrophy.

Abbreviations and Acronyms

ECG = electrocardiography
ESC = European Society of Cardiology
PPS = pre-participation screening
SCD = sudden cardiac death

Definitions. Nonathletes were defined as individuals not involved in regular, organized competitive team or individual sports, including sedentary individuals and those exercising recreationally. Athletes were defined as individuals competing in organized team or individual sports at regional, national, or international levels with a high premium on athletic excellence. Ethnicity was self-reported. Adolescents were defined as individuals <18 years of age.

Twelve-lead ECG. A resting 12-lead ECG was performed with the use of a Philips Pagewriter Trim III recorder (Philips, Bothell, Washington) with a paper speed of 25 mm/s and amplification of 0.1 mV/mm. P-, Q-, R-, S-, and T-wave voltages; ST-segments; QRS duration; PR-interval and QT-interval were measured in each lead with the use of callipers. The highest value was quoted as the absolute QT. Heart rate and QRS axis were calculated. ECG definitions were consistent with the 2010 ESC position paper (5).

Sinus bradycardia was defined as heart rate <60 beats per minute and first-degree AV block as PR-interval >200 ms. Incomplete right bundle-branch block was defined by rSR^{I} morphology of the QRS complex <120 ms in lead V_1. Early repolarization was defined as an elevated J-point ≥1 mm in ≥2 contiguous leads with notching and/or slurring of the terminal QRS complex. Sokolow-Lyon voltage criteria were used for left ventricular hypertrophy ($S_{V1} + R_{V5} \geq 35$ mm) and right ventricular hypertrophy ($R_{V1} + S_{V5} \geq 10.5$ mm). T-wave inversion was defined as ≥2 mm in ≥2 contiguous leads excluding AVR, V_1, and III. ST-segment shift was considered significant if ≥1 mm in ≥2 contiguous leads. Pathological Q-waves were defined as ≥2 mm in depth in ≥2 contiguous leads. Left atrial enlargement was identified as a biphasic P-wave in lead V_1 in which the negative portion was ≥1 mm deep and ≥40 ms (8). Right atrial (RA) enlargement was identified by the presence of a P-wave >2.5 mm in lead II and/or >1.5 mm in lead V_1. Left-axis deviation and right-axis deviation were defined as ≤−30° and ≥+120°, respectively. Intraventricular conduction abnormalities of right bundle-branch block and left bundle-branch block morphology were identified when the QRS duration was ≥120 ms. The QT-interval was measured by means of the tangent method and corrected for heart rate with the use of Bazett's formula (9). Long-QTc interval was defined as >440 ms (men) and >460 ms (women); short-QTc interval was defined as QTc <380 ms. Brugada-like early repolarization changes were identified as J-point elevation ≥2 mm with down-sloping "coved" or "saddle-back" ST-segment elevation in leads V_1–V_3.