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Commentary

How the New International recommendation for Electrocardiographic interpretation in Athletes would change our practice

Introduction

Recent evidences in the prevention of sudden cardiac death (SCD) confirmed the importance of pre-participation cardiovascular screening in athletes to early identify, and further disqualify from the competition, all the athletes, if any, affected by life-threatening serious cardiac pathologies that can lead to SCD [1-2]. At present, there is no consensus regarding the optimal strategy for athletes' pre-participation screening. However, previous data showed that adding the ECG to pre-participation screening evaluation increased the accuracy to detect an underlying cardiovascular disease, in comparison with physical examination and medical history alone [3-4].

In the past, different criteria have been proposed, so a team of experts in sports cardiology aimed to standardize the criteria in ECG interpretation, in order to achieve the maximum sensibility and to improve the specificity, because of the number of false positive is strictly related with the type of criteria and the experience of the operators.

In 2010 the European Society of Cardiology published the recommendations for interpretation of 12-lead electrocardiogram in the athletes with the main objective to differentiate the physiological sport-related adaptive ECG changes observed in athletes from the pathological ECG findings suggestive for cardiovascular disease [5].

Then in Seattle in 2012, an international team of experts wrote the so-called the "Seattle Criteria", a revision of ECG interpretation criteria in athletes, in order to increase the specificity without reducing the sensibility of the previous ESC 2010 recommendations [6].

However, the Seattle criteria were based only on Caucasian athletes and they did not describe some ECG findings that are considered a normal variant in some ethnicity. In particular, Afro-American athletes usually show ECG alterations apparently related to cardiomyopathy [7, 8], but are normal variant. So in 2014 the "Refined Criteria" were published [8].

In February 2015, in Seattle, a consensus of experts updated the current standard criteria for ECG interpretation in asymptomatic athletes from 12 to 35 years of age. These criteria are based on the latest scientific knowledge and provided physician with a useful tool to accurately recognize the ECG anomalies related to exercise-induced normal finding and exercise-unrelated pathological abnormalities potentially related to SCD in athletes [8].

The New Recommendations

The electrocardiographic findings are divided in three categories: normal, abnormal and borderline.

Normal ECG findings in athletes

This section describes the normal ECG findings in athletes, including all the ECG aspects related with physiological cardiac adaptation to training, in absence of any other signs suggestive for cardiac pathology.

In example, signs of left or right ventricular hypertrophy are related to the increased dimension of cardiac chamber and correspond to isolated increased QRS voltage criteria without other ECG anomalies. The athlete's heart is characterized by a homogeneous increase of the four chambers' dimensions, wall thickness and ventricular mass, while early stages of cardiomyopathy may have an asymmetric distribution between the chambers.

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The early repolarization is a frequent pattern in the athletes' ECG and it is a sign of physiologic heart adaptation to exercise, especially in young athletes, in males and Afro-American ethnicity, compared to sedentary people.

In 2 out of 3 of Afro-American athletes, the early repolarization is associated with T wave inversion in anterior leads (V1-V4) and the physician should consider these anomalies as a benign pattern, like it was described in the Seattle Criteria of 2012.

The authors introduced the concept of "ECG juvenile pattern", when there is the presence of T wave inversion and biphasic T wave in young athlete who have not reached physical maturity [9]. In particular, in peri-pubertal athletes, the presence of TWI in the anterior leads is not associated with a structural cardiomyopathy [10] (Figure 1).

Among the most frequent electrocardiographic findings in the athletes, the authors included some physiological arrhythmias caused by an increased vagal tone. For example: sinus bradycardia (>30bpm), sinus arrhythmia, less common first-degree atrio-ventricular (AV) block and second-degree AV block type 1 (Wenckebach phenomenon). Among the abnormal ECG findings, Sharma et al. [8], clarified that a sinus bradycardia less than 30 bpm or a first-degree AV block more than 400 msec should require further investigations for cardiac conduction disease, for instance in this cases the physician could evaluate the chronotropic response of the athlete with mild aerobic activity.

The physician should take into account that many other factor like the level and duration of training, the type of sport competition and the aerobic capacity of the athlete can play an important role inducing exercise-related changes. For example the athletes that compete in endurance physical activities like biking, ultramarathon, cross-country skiing, rowing/canoeing, have been shown to be significantly associated with a higher rate of ECG abnormalities related to physiological heart adaptations to physical exercise as sinus bradycardia or increased QRS voltage [11].

Abnormal electrocardiogram findings in athletes

Sharma et al. [8], defined all the abnormal ECG findings in athletes that need further investigations, initially by echocardiography and then if results are doubtful, by cardiac resonance imaging (CMR) in order to exclude or confirm the suspicion of an underlying cardiovascular pathology.

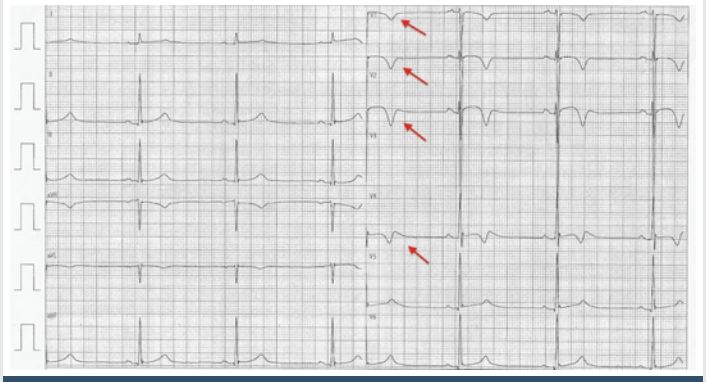

Figure 1: The ECG above shows a typical "juvenil pattern" with T wave inversion in antero-septal leads: a normal ECG findings in young athletes.

The T waves inversion in two or more consecutive leads, as anterior, lateral, infero-lateral or inferior distributions (except in avR, III or V1), are considered abnormal and should require further examinations in suspicion of hypertrophic cardiomyopathy (HCM) or arrythmogenic right ventricular cardiomyopathy (ARVC).

A S-T segment depression of more than 0.5 mm (0.05 mV) in two or more leads is abnormal and it should be further investigated by echocardiography to exclude an underlying structural heart disease.

Pathological Q waves are always considered abnormal, potentially suggestive of HCM, ARVC, infiltrative cardiomyopathies, myocardial infarction and electrical accessory pathways. These ECG findings have been reported in approximately 1-2% of all athletes, and may have an higher prevalence in males and Afro-American athletes.

In the previous ESC consensus papers, pathological Q waves were defined as >3mm in depth or >40 msec in duration in two or more leads (except III and aVR) [12]. However, adopting these criteria can induce a high rate of false positive, especially in trained athletes with physiological left ventricular hypertrophy or in thin adolescent athletes. The authors introduce a new parameter to reduce the rate of false positive, the Q/R ratio that normalize the Q waves depth to the degree of previous R waves (Q/R ratio pathological > 0,25 or > 40 msec in duration) [6].

A Left Bundle Block Branch (LBBB) represents an abnormal finding in the athlete and suggests the presence of coronary artery disease or cardiomyopathy and must be further evaluated. A nonspecific intraventricular conduction delay (IVCD) is still an unclear ECG finding even thought some studies considered this alteration as a combination of neuronally mediated conduction fiber slowing and increased myocardial mass [13].

In these new recommendations the cut-off of IVCD is 140 msec, which is different from the ESC 2010 or "Refined Criteria" 2014 (120msec), but not from the "Seattle Criteria" 2012 [12].

Another cause of sudden cardiac death in athletes is ventricular pre-excitation, where there is an accessory pathway, which bypasses the AV node a faster and aberrant conduction to the ventricle (pre-excitation). In case of atrial fibrillation, this alteration could determinate ventricular fibrillation. Typical findings in ventricular pre-excitation are: PR interval < 120 msec, presence of delta waves and wide QRS > 120 msec.

The Long QT syndrome (LQTS) is a rare congenital heart disease that increases the risk of ventricular arrhythmia, characterized by the presence of prolongation of the QT interval. The QT interval is calculated by Bazett's heart rate correction (QTc). For the interpretation of QTc, Sharma et al. [8] used the same cut off as the Seattle Criteria 2012, that

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introduced less restricted limits for abnormal QTc interval than the ESC criteria (QTc > 470 msec in male and QTc > 480 msec in female) [12].

An occasional finding of a prolonged QTc in an athlete needs further investigation. It should be investigated the presence of syncope or seizure in the personal history and the presence of exertional syncope, seizures, suddenly cardiac death < 50 years in the family history; if these risk factors are positive these athletes should be referred to an electrophysiologist for a specific evaluation. If an athlete shows prolonged QTc is important to exclude reversible cause or extrinsic factors (electrolyte abnormalities, drugs therapy etc..), and in selected case, the application of Schwartz-Moss scoring system, stress ECG, provocative testing, genetic analysis can be very helpful. The Schwartz-Moss scoring takes into account all the diagnostic criteria for LQTS (positive family history of unexplained SCD, clinical history of syncope or congenital deafness, prolonged QTc and other ECG findings) [14]. There is not a specific cut-off for short QT interval but a recent study validated a cut-off of 320 msec for the short QT interval in young individuals. Due to the lack of data in asymptomatic athletes, the consensus suggested further examination only in athletes with risk factors.

The Brugada syndrome is an inherited channelopathy that increases the risk of sudden cardiac death causing potentially life-threatening arrhythmias during increased vagal tone. There are three Brugada's ECG patterns but only the type 1 is diagnostic and its features are: rSr' morphology, ST elevation > 2mm and terminal T wave inversion, in leads V1 to V3. The Corrado Index is a useful method to distinguish Brugada tipe 1 pattern from early repolarization in an athlete. This Index measures the ST elevation at the beginning of ST segment/J point elevation (STJ) and 80msec after the beginning of the segment (ST80). The ECG is suggestive of Brugada tipe 1 pattern if the downsloping ST segment has a STJ/STJ80 ratio > 1 [15]. For a correct evaluation of Brugada pattern is important an appropriate lead placement and, if necessary, to perform the ECG with V1 and V2 lead in the second and third intercostal space.

A high-grade AV block, Mobitz type 2, second degree and third degree are abnormal findings in athletes and always need further investigations.

Multiple premature ventricle contractions (PVC ≥2) are rare findings at tbe 12-lead ECG in athletes, and they can be suspicious for an underlying heart disease. In this situation, the pre-participation screening should be integrated with 24-hour ECG Holter, echocardiography and an ECG stress test to evaluate if exercise suppresses the PVCs. In selected cases, a contrast enhanced CMR or an invasive electrophysiology study might be appropriate.

The most common form of benign atrial tachyarrythmias is the sinus tachyarrythmias. Supraventricular tachyarrythmias, atrial fibrillation, and atrial flutter are rarely seen in athletes and they are considered pathological findings. These arrhythmias need to be evaluated with further assessments in particular when associated with other heart disease (LQTS, WPW, Brugada like syndrome, myocarditis etc..). First of all, an echocardiography should be performed in order to exclude structural or functional cardiomyopathies, and consider anti-coagulant therapy based on standard guidelines.

The ventricular arrhythmias (couplets, triplets, and non-sustained ventricular tachyarrhythmias) are included in the abnormal findings and always require further investigations.

In athletes > 30 years of age is important to exclude the presence of coronary artery disease searching for T waves inversion, pathological Q waves, left or right bundle branch block, S-T segment elevation, abnormal R waves progression, left anterior emiblock and atrial fibrillation in the ECG.

Athletes, who have ECG abnormalities suggestive for cardiomyopathies, but without an overt expression, should be followed also after the end of their competitive career.

All the athletes that present abnormal electrocardiogram findings should be disqualify from the competition until the conclusion of secondary examinations. If the exams don't show any evidence of structural heart disease, the athletes could be eligible for competition with a closer follow up.

Borderline electrocardiogram findings in athletes

The Seattle Consensus 2015, the Refined Criteria 2014, unlike ESC recommendations 2010 or Seattle Criteria 2012, introduce a new section of borderline ECG findings. These ECG findings do not need further investigation if they are present in athletes without other symptoms or family history of SCD or other cardiomyopathies.

Sharma et al. [8], considered left atrium enlargement (LAE), right atrium enlargement (RAE), left axis deviation (LAD), right axis deviation (RAD), right ventricular hypertrophy (RVH) as borderline findings. Previous studies from Zaidi et al. [16], and Gati et al. [17], demonstrated that in asymptomatic athletes the presence of these ECG findings, either in isolation or in associations with recognized training-related ECG changes, correlates extremely poorly with serious cardiac pathology [16-17].

Previously the ESC recommendations 2010 and the Seattle criteria 2012 classified these ECG findings as abnormal, in particular LAE, because they are common features in HCM. However, in HCM, usually coexist a multitude of other ECG abnormalities such as T wave inversion, Q waves and ST segment depression [6]. These borderline ECG finding are considered not significant if isolated and no further evaluation by echocardiography should be performed, while the same borderline ECG finding must be considered abnormal if associated to other findings suggestive for abnormalities. Among the borderline criteria the complete right bundle branch block is also included, which is a very common finding in the young athletes. The right delay conduction, complete or incomplete, can represent an ECG finding of structural and functional cardiac remodelling that comes from physiological adaptations to physical exercise. For example, right ventricular

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hypertrophy determined a prolonged QRS and a relative reduction of right ventricular systolic function at rest.

The identification of borderline ECG anomalies has improved the specificity without reducing the sensibility of the ECG criteria and this is very important for different reasons.

First of all increasing the specificity determines a cost reduction of pre-participation screening, in fact the low rate of false positive reduces the numbers of further examinations (ranging from echocardiography to CMR). Nowadays, the cost reduction plays a central role in the scientific debate about the effectiveness of 12-lead ECG in the pre-participation screening in athletes. Part of the scientific community believes that the addiction of this exam to the screening is too expensive considering the large number of exercising young individuals and the low incidence of exercise-related sudden cardiac death [18-19].

In addition the increase of sensibility, achieved by the inclusion of LAE, RAE, LAD, RAD and RVH among the borderline findings is very important for professional athletes in whom disqualification from competitive sports has significant physical, psychological and financial consequences. However the physicians, should consider borderline ECG criteria (LAD, RAD, LAE, RAE, RVH) taking into account all the athlete's features (ethnicity, age, sex, kind of spot, family history, personal history, body habitus, etc..), and not only categorizing the athletes in one of the ECG findings.

For instance the study of Zaidi et al. [16], showed that RVH appears to be a benign phenomenon that is almost observed in males and which fails to discriminate between physiology and disease. RVH by voltage criteria (Sokolow Lyon Index: R in V1 + S in V5 or V6 >1,05 mV), reflects the influence of factors such as chest wall morphology and body habitus on the magnitude of QRS. At the same time the physician should evaluate carefully borderline findings. The inclusion of atrial enlargement and atrial axis deviations in the category of borderline findings, on the one hand causes an increase of specificity from 90% to 94%, and on the other hand a reduction of sensibility from 91% to 89%. In fact the study of Gati et al. [17], shows that LAD, RAD, LAD and RAD could be isolated ECG expressions of mild form of hypertrophic cardiomyopathy.

The athletes that present electrocardiogram borderline findings in association with positive familiar history of cardiac disease or symptomatic athletes, should warrant further examinations in order to exclude the presence of cardiac disease.

The pre-participation screening for sport competition should be repeated every year in order to early detect sings of possible pathologies that can be a cause of sudden cardiac death.

In those athletes that present ECG abnormalities, compatible with cardiac pathologies, in absence an overt cardiac disease, should be followed with several evaluations, depending on individual circumstances.

Final Considerations

The new recommendations are the results of many years of studies about the correct criteria to adopt in the ECG interpretations of young athletes. The scientific literature confirms that adding the ECG to family and personal history and to physical examination increase the physician's ability to detect the mostly of the pathologies implicated in sudden cardiac death, with a higher sensibility than a screening based only on physical questionnaire and physical examination.

The application of standardized criteria in the evaluation of athlete's ECG improved interpretations accuracy and also reduced the interoperator variability [20-21].

The false positive rate in the pre-participation athlete's

Table 1: Comparison of the previous criteria for ECG interpretation in athletes and the actual international recommendation.
AV - atrio-ventricular; IVCD - interventricular conduction delay; LAD - left axis deviation; LAE - left atrial enlargement; LBBB - left bundle branch block; LVH - left ventricular hypertrophy; PVC - premature ventricular contraction; RAD - right axis deviation; RAE - right atrial enlargement; RBBB - right ventricular bundle branch block; RVH - right ventricular hypertrophy; TWI - T-wave inversion.

ECG findings in athletes 12-35y	ESC 2010	SEATTLE CRITERIA 2012	REFINED CRITERIA 2014	INTERNATIONAL RECOMMENDATIONS 2017
Isolated LVH	✓	✓	✓	✓
Incomplete RBBB	✓	✓	✓	✓
Early repolarization	✓	✓	✓	✓
ST elevation followed by TWI in Afro-American athletes (V1-V4)	X	X	✓	✓
TWI (V1-V3) < 16y	X	X	X	✓
Sinus bradycardia ≥ 30 bpm	✓	✓	✓	✓
Ectopic atrial or junctional arrhythmia	✓	✓	✓	✓
First-degree AV block	✓	✓	✓	✓
Mobitz type 1 second-degree AV block	✓	✓	✓	✓
LAD; RAD; LAE; RAE; RVH	✓	✓	✓	✓
Incomplete RBBB	✓	✓	✓	✓
Complete RBBB	✓	✓	✓	✓
TWI	✓	✓	✓	✓
ST-segment depression	✓	✓	✓	✓
Pathologic Q waves	✓	✓	✓	✓
Complete LBBB	✓	✓	✓	✓
IVCD	✓	✓	✓	✓
Epsilon waves	✓	✓	✓	✓
Ventricular pre-excitation	✓	✓	✓	✓
Abnormal QT segment duration	✓	✓	✓	✓
Brugada type 1	✓	✓	✓	✓
Sinus bradycardia < 30 bpm	✓	✓	✓	✓
Mobitz type 2 II AV block or III AV block	✓	✓	✓	✓
≥ 2 PVCs	✓	✓	✓	✓
Atrial or ventricular arrhythmias	✓	✓	✓	✓

Abbrevation: Normal: ✓; Borderline: ✓; Abnormal: ✓; Not present: X

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screening is strictly related to the criteria used to evaluate electrocardiography, and to the experience and the ability of the physician. Obviously these recommendations are useful for a correct evaluation of ECG but the physician have to consider the inter-individual variability and all the factors the can influence the interpretation (ethnicities, age, sex, kind of sport, family and personal history).

The real efficacy of these new recommendations will be evaluated after the clinical application, in term of their sensibility to detect cardiomyopathies and especially in term of specificity to reduce the number of false positive. This latest aspect is important to warrant saving financial resources related to athlete's screening and to oppose the skepticism about the effectiveness of ECG in the pre-participation screening of the athlete.

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