BRIEF REPORT

Abnormal ECG Findings in Amateur Athletes: Comparison of the 2013 and 2017 Seattle Criteria

Hallazgos electrocardiográficos anormales en deportistas amateur: comparación de los criterios de Seattle 2013 y 2017

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ABSTRACT

Background: The specificity of the electrocardiogram as a diagnostic tool for causes of sudden cardiac death in athletes depends on the criteria used to discern between physiological and pathological alterations.
Objectives: To assess the prevalence of abnormal electrocardiographic (ECG) findings in amateur athletes when comparing the 2013 and 2017 Seattle Criteria.
Methods: A total of 853 athletes were evaluated. Gender and age were evaluated as independent predictor variables. Follow-up was carried out by means of complementary diagnostic methods.
Results: A total of 29 athletes presented abnormal electrocardiograms according to 2013 criteria, and 17 athletes according to 2017 criteria, constituting 3.4% and 2% of cases, respectively. No significant differences were found between gender or age.
Conclusions: Among the ECG considered abnormal according to the 2013 criteria, 41.4% were considered normal when applying the criteria redefined in 2017. Neither gender nor age are independent predictor variables. In none of the patients heart disease could be demonstrated during follow-up.

Key Words: Key words: Sudden Cardiac Death – Electrocardiography – Athlete – Cardiomyopathy

RESUMEN

Introducción: La especificidad del electrocardiograma como método diagnóstico de causas de muerte súbita cardíaca en depor¬tistas depende de los criterios utilizados para discernir entre alteraciones fisiológicas y patológicas.
Objetivos: Evaluar la prevalencia de hallazgos electrocardiográficos anormales en deportistas amateur al comparar los Cri¬terios de Seattle 2013 y 2017.
Material y métodos: Fueron evaluados 853 deportistas. Se evaluaron género y edad como variables predictoras independientes. Se realizó un seguimiento mediante métodos complementarios de diagnóstico.
Resultados: Presentaron electrocardiogramas anormales según criterios 2013 29 deportistas y 17, según criterios 2017, lo que constituyó el 3,4% y el 2%, respectivamente. No se encontraron diferencias significativas entre géneros ni por edad.
Conclusiones: De los electrocardiogramas considerados anormales según los criterios 2013, el 41,4% pasó a considerarse normal al aplicarse los criterios redefinidos en 2017. Ni el género ni la edad constituyen variables predictoras independientes. En ningún evaluado, se pudo demostrar cardiopatía en el seguimiento.

Palabras clave: Muerte súbita cardíaca - Electrocardiografía - Atletas - Cardiomiopatías

Abbreviations

AVB	Atrioventricular block	**2013NECG**	Normal electrocardiogram based on the 2013 Seattle Criteria
CRBBB	Complete right bundle branch block	**2017NECG**	Normal electrocardiogram based on the 2017 Seattle Criteria
CLBBB	Complete left bundle branch block	**VE**	Ventricular extrasystole
ECG	Electrocardiogram	**HR**	Heart rate
2013AECG	Abnormal electrocardiogram based on the 2013 Seattle Criteria	**LVH**	Left ventricular hypertrophy
		bpm	Beats per minute
2017AECG	Abnormal electrocardiogram based on the 2017 Seattle Criteria	**SCD**	Sudden cardiac death
		NICD	Nonspecific intraventricular conduction delay

Rev Argent Cardiol 2019;87:145-148. http://dx.doi.org/10.7775/rac.v87.i2.14621

Received: 9/23/2018 – *Accepted:* 12/17/2018

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INTRODUCTION

Sudden cardiac death (SCD) is the main cause of death during sports practice. (1) Screening sensitivity to detect underlying cardiac disease causing SCD increases with the inclusion of ECG, although its poor specificity is a challenge when it comes to disqualifying an athlete, since sport practice is the cause of physiological electrocardiographic changes that must be differentiated from abnormal alterations. In order to improve ECG specificity, the Seattle Criteria were published in 2013, and redefined in 2017. Our objective was to assess the prevalence of abnormal ECG findings in amateur athletes according to both criteria, and to assess gender and age as independent predictor variables.

METHODS

At our sports institution, an annual physical examination is mandatory, including anamnesis, physical examination and ECG as basic screening. Abnormal electrocardiographic changes were sought in 853 amateur athletes (518 males) aged 12-35 years (median age 16 years) according to the 2013 Seattle Criteria and the 2017 redefined criteria. ECG findings are presented as normal according to the 2013 Seattle Criteria (2013NECG) when no electrocardiographic alterations are found or when ECG presents one or more NON-pathological changes according to that consensus. (2) ECG findings are presented as normal according to 2017 Seattle Criteria (2017NECG) when no electrocardiographic alterations are found or when ECG presents one or more NON-pathological changes according to that consensus, or one (and no more than one) 'borderline' change. (3) An ECG is considered abnormal according to 2013 Seattle Criteria (2013AECG) when it presents at least one of the findings consistent with structural or electrical cardiac disorders, as detailed in Table 1. Although the 2013 Seattle consensus for recognizing changes suggestive of cardiomyopathy (4) does not consider complete right bundle branch block (CRBBB) or nonspecific intraventricular conduction delay (NICD) as abnormal (provided QRS duration is <0.14 s), the 2013 Seattle consensus for normal ECG findings in athletes (2) considers any intraventricular conduction delay <0.12 s as normal; therefore, following Drezner et al (6), we argue that any CRBBB or NICD ≥ 0.12 s should require additional diagnostic tests according to 2013 criteria. An ECG is considered abnormal according to 2017 Seattle Criteria (2017AECG) when it presents at least one of the findings consistent with heart disease detailed in Table 2, or two or more 'borderline' changes. (3) T wave inversion in V1-V3 is considered normal in athletes up to 16 years of age, and in V2 -V4 in black athletes if preceded by J point elevation and convex ST segment. T-wave inversion in V5-V6 is considered abnormal according to the 2017 criteria (2013 criteria required T-wave inversion in both leads). The rest of the definitions are detailed in Tables 1 and 2. The electrocardiographic criteria established in the 2013 (2, 4-7) and 2017 (3) Seattle Consensus were followed. Prevalence by gender and age were compared in 2013AECG vs. 2017AECG.

This was a descriptive, extensive sample, multivariate, cross-sectional study. The study population included athletes from our sports institution who underwent control physical examination studies between 2010 and 2015.

Statistical analysis

Pearson's chi-square test was used to compare qualitative variables. The Mann-Whitney non-parametric test was used to compare the quantitative variable 'age' between groups, expressed as median and interquartile range (IQR). A two-tailed p-value <0.05 was considered as significant. Frequency distribution of abnormal electrocardiographic changes was depicted. SPSS statistical package was used to perform the analyses.

Ethical considerations

The studys was approved by the institutional Ethics Committee.

RESULTS

A total of 60.7% assessed athletes were male. Median age was 16 years (IQR 6), with no significant gender

Table 1. Electrocardiographic findings consistent with heart disease and primary electrical disease according to 2013 Seattle Criteria

T wave inversion	> 1 mm in depth in 2 or more contiguous leads V2– V6 , DII and aVF, or DI and aVL (excluding DIII, aVR and V1)
ST-segment depression	≥ 0.5 mm in 2 or more contiguous leads
Pathological q wave	> 3 mm in depth or > 0.04 sec in duration in 2 or more leads (excluding DIII and aVR)
CLBBB	QRS ≥ 0.12 sec, mostly negative QRS complex in V1 (QS or rS) and monophasic R wave in DI and V6
Left axis deviation	Axis -30 to -90 degrees
Left atrial enlargement	P wave > 0.12 sec in DI or DII, with negative component in V1 ≥ 1 mm in depth and ≥ 0.04 sec in duration
Right atrial enlargement	P wave amplitude ≥ 2.5 mm in DII, DIII or aVF
RVH	R in V1 + S in V5 > 10.5 mm with axis > 120 degrees
QRS duration ≥ 140 ms	
CRBBB	QRS ≥ 0.12 sec with rSR' pattern in V1 and S wave of greater duration than R wave in V6
NICD	QRS ≥ 0.12 sec with no specific pattern of CRBBB or CLBBB
Epsilon wave	Negative deflection immediately after QRS in V1 or V2
PR interval ≥ 300 msec	
Second degree AVB Mobitz 2	Intermittent non-conductive P wave not preceded by prolonged PR interval or followed by short PR
Third degree AVB	Complete AVB
Ventricular pre-excitation	PR interval < 0.12 sec with delta wave and QRS > 0.12 sec
Long Qt *	QT interval corrected by heart rate ≥ 0.47 sec in men and 0.48 sec in women
Short Qt *	QT interval corrected by heart rate ≤ 0.32 sec
Type-1 Brugada	High take-off and downsloping ST segment elevation followed by a negative T wave in 2 or more leads in V1 - V3
Bradycardia	HR < 30 bpm or sinus pause ≥ 3 sec
Ventricular extrasystole	Two or more VE in a tracing of 10 sec
Supraventricular tachyarrhythmia	Supraventricular tachycardia, nodal reentry tachycardia, atrial flutter, atrial fibrillation
Ventricular arrhythmia	Couplets or nonsustained ventricular tachycardia

*Ideally, QT interval corrected by HR is measured with HR of 60 – 90 bpm. Repeating the ECG for borderline or abnormal QTc values with a HR < 50 bpm after mild aerobic activity should be considered. CLBBB: Complete left bundle branch block, LAE: Left auricular enlargement, RAE: Right auricular enlargement, LVH: Left ventricular hypertrophy, CRBBB: Complete right bundle branch block, NICD: Nonspecific intraventricular conduction delay, AVB: Atrioventricular block, VE: Ventricular extrasystole, HR: Heart rate, Bpm: Beats per minute. Adapted from "Abnormal electrocardiographic findings in athletes: recognising changes suggestive of cardiomyopathy"; Drezner JA, Ashley E, Baggish A, et al. Br J Sports Med. 2013; 47: 137-152, and from "Abnormal electrocardiographic findings in athletes: recognising changes suggestive of primary electrical disease"; Drezner JA, Ackerman MJ, Cannon BC, et al. Br J Sports Med. 2013; 47: 153-167 with the authorization of BMJ Publishing Group Ltd.

Table 2. Electrocardiographic findings consistent with primary electrical disease according to 2017 Seattle Criteria

T wave inversion	≥ 1 mm in depth in two or more contiguous leads; excludes leads aVR, III and V1
ST segment depression	≥ 0.5 mm in depth in two or more contiguous leads
Pathological Q waves	Q/R ratio ≥ 0.25 or ≥ 0.40 ms in duration in two or more leads (excluding III and aVR)
Complete left bundle branch block	QRS ≥ 0.12 s, predominantly negative QRS complex in V1 (QS or rS) and monophasic R wave in L1 and V6
Any QRS duration ≥ 140 ms	
Epsilon wave	Negative deflection immediately after QRS in V1 or V2
Ventricular pre-excitation	PR interval < 0.12 s with delta wave and QRS > 0.12 s
Long QT*	Corrected QT interval ≥ 0.47 s in men and ≥ 0.48 s in women
Brugada type 1 pattern	Cove-type ST segment elevation and gradually descending ST-segment followed by a negative T wave in 2 or more leads in V1 to V3
Profound sinus bradycardia	< 30 beats per minute or sinus pauses ≥ 3 s
PR interval > o = a 400 ms	
Mobitz type II 2° atrioventricular block	Intermittently non-conducted P waves with a fixed PR interval
3° atrioventricular block	Complete heart block
Ventricular extrasystole	Two or more ventricular extrasystoles per 10 s tracing
Supraventricular tachyarrhythmia	Supraventricular tachycardia, atrial flutter, atrial fibrillation
Complex ventricular arrhythmia	Couplets or non-sustained ventricular tachycardia
Left axis deviation	Axis from -30° to -90°. In the presence of concomitant LAE, right axis deviation, RAE or CRBBB
Left atrial enlargement	P wave duration > 0.12 in LI or LII, with negative P wave in V1 ≥ 1 mm in depth and ≥ 0.04s in duration. In the presence of concomitant left axis deviation, right axis deviation, RAE o CRBBB.
Right axis deviation	> 120°. In the presence of concomitant left axis deviation, LAE, right axis deviation or CRBBB.
Right atrial enlargement	P wave ≥ 2.5 mm in II, III of aVF. In the presence of concomitant left axis deviation, LAE, right axis deviation, or RAE.
Complete right bundle branch block	rSR´pattern in lead V1 and an S wave wider than R wave in lead V& with QRS duration ≥ 120 ms. In the presence of concomitant left axis deviation, LAE, right axis deviation,or RAE.

International consensus standards for ECG interpretation in athletes: definitions of ECG criteria. CLBBB: complete left bundle branch block, HR: heart rate, AVB: atrioventricular block, VE: ventricular extrasystole, LAE: left atrial enlargement, RAE: right atrial enlargement, CRBBB: complete right bundle branch block. Adapted from International criteria for electrocardiographic interpretation in athletes: consensus statement, Drezner JA, Sharma S, Baggish A, et al. Br J Sports Med. 2017; 51: 704-731 with authorization of BMJ Publishing Group Ltd. (4)

differences. The 2013NECG and 2013AECG prevalence was 96.6% and 3.4%, respectively, with median age 16 (IQR 6) and 17 (IQR 5) years. The 2017NECG and 2017AECG prevalence was 98% and 2%, respectively, with median age 16 (IQR 6) and 17 (IQR 6) years. No significant gender differences were found when comparing 2013NECG vs. 2013AECG prevalence and 2017NECG vs. 2017AECG prevalence.

Among the 29 2013AECG athletes, 18 were male (62.1%). Of the 17 2017AECG athletes, 11 were male (64.7%). Twelve (7 men and 5 women) among the 29 2013AECG (41.4%) were redefined as normal when 2017 Seattle Criteria were applied. No significant gender or age differences were found when comparing the prevalence of abnormal ECG findings for both criteria, nor when comparing the 2017AECG prevalence with the ECG prevalence that was considered normal according to the redefined criteria. Figure 1 describes the frequency of abnormal ECG alterations according to 2013 and 2017 criteria. In no case was heart disease demonstrated by complementary methods. In our study, the low prevalence does not allow the use of a statistical test to adequately correlate with training load or type of sport. The authors declare no conflicts of interest concerning the topic of the study.

DISCUSSION

We will discuss three of the studies that determine the prevalence of abnormal electrocardiographic findings in athletes. The study by Pelliccia and Maron (8) in 2000 classified ECGs of 1,005 athletes (24 ±6 years, 75% men) into 3 subgroups: "distinctly abnormal", "mildly abnormal", and "normal or with minor alterations". The authors considered voltage criteria for left ventricular hypertrophy (LVH) as abnormal, which are considered normal in the 2013 and 2017 Seattle Criteria when presenting alone. Negative T-wave by age or lead was not discriminated, and vagotonic T waves were considered as "mildly abnormal". R wave progression in precordial leads and right axis deviation were also considered abnormal. These differences explain the contrast with our study in the prevalence of "abnormal" ECGs (40%). However, if in our study we considered as abnormal the positive cases for voltage criteria, right axis deviation and T wave inversion in any 2 or more leads, the conclusions of Pelliccia and Maron would become close to ours, particularly in the case of 15 to 36 year-old male athletes. In the Pelliccia study in 2007 (9), on 32,652 subjects (80% male, mean age 17 years), the prevalence of abnormal electrocardiograms reached 11.8%, although this is reduced to 4.8% when those considered by the same authors as physiological (early repolarization pattern, incomplete right bundle branch block and prolonged PR interval) are ruled out. This percentage is very close to the 3.4% found in our study for the 2013AECG, even considering that Pelliccia did not include the Epsilon wave and the short QT interval as abnormal, although he contemplated the isolated voltage criteria for LVH as abnormal and was based on a still soft definition of pathological negative T wave. Thirdly, we will consider the study by Brosnan et al (2014) (10), who found an abnormal ECG prevalence of 4.5% based on the 2013 Seattle Criteria in 1,078 Australian athletes aged 16-34 years. A false positive rate of 17% was obtained according to the 2010 Recommendations of the European Society of Cardiology, (11) which was reduced to 4.2% based on the 2013 Seattle Criteria. Regarding the implementation of the 2017 Seattle Criteria, it is important to notice the study by Zorzi et al. (12) comparing these criteria with those of 2010 (11) for the differential diagnosis between hypertrophic cardiomyopathy and athlete heart. In that study, a statistically significant increase in specificity is observed (from 86.9% to 95.9%)

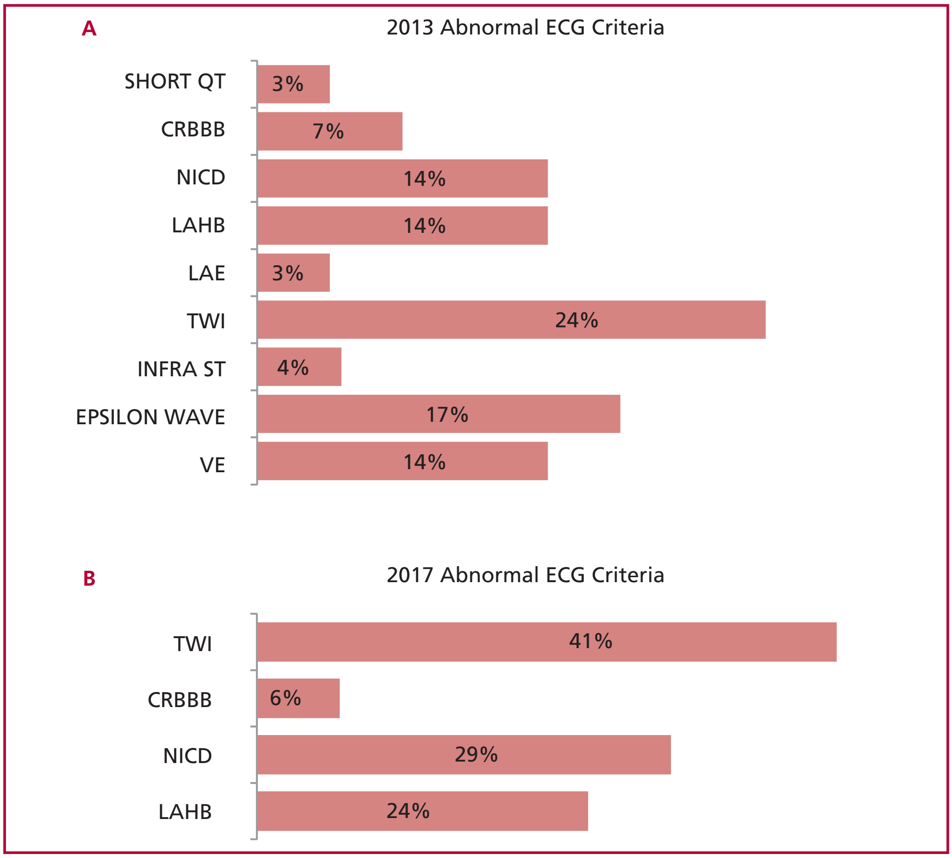

Fig. 1. Prevalence of abnormal alterations according to 2013 (A) and 2017 (B) criteria. CRBBB: Complete right bundle branch block. NICD: Nonspecific intraventricular conduction delay. LAHB: Left anterior hemiblock. LAE: Left atrial enlargement. TWI: T-wave inversion. VE: Ventricular extrasystole.

according to the 2017 Criteria with a non-significant reduction in sensitivity.

Limitations

The results of this study may not apply to other populations due to demographic, ethnic, and sports-related differences that are not represented in our population.

CONCLUSIONS

The prevalence of abnormal ECG findings decreases from 3.4% to 2% when the Seattle Criteria redefined in 2017 are applied in amateur athletes. Among the ECG considered abnormal according to the 2013 Seattle Criteria, 41.4% were considered normal when applying the criteria redefined in 2017. Neither gender nor age are independent predictor variables. Heart disease could not be demonstrated in any of the athletes undergoing complementary diagnostic methods.

Conflicts of interest

None declared.

(See authors' conflicts of interest forms on the website/ Supplementary material)

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