Prevalence of electrocardiographic abnormalities in elite and sub-elite professional athletes

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Summary

Objective: The objective of this study is to determine the prevalence of electrocardiographic abnormalities that could endanger the lives of elite and sub-elite professional athletes based on normal, borderline, and abnormal findings described in international recommendations.
Material and method: This retrospective observational study was performed only on men elite football players, men elite baseball players, men elite basketball players, and men sub-elite football players (second division, third division, U-15, U-17, and U-20). Data were collected from pre-competition ECGs performed by team-affiliated physicians in the 2012 – 2019 preseasons of active-roster athletes and sub-elite players. The qualitative characteristics of each ECG were analyzed using the international recommendations for electrocardiographic interpretation in athletes to detect accepted training-related ECG findings and findings classified as borderline and abnormal.
Results: A total of 716 ECGs were included. Common training-related ECG changes were found in 63.1%; sinus bradycardia was the most prevalent training-related ECG change (47.2%). The prevalence of borderline ECG readings among all the participants was 3.9%; the most frequent change was right axis deviation. The prevalence of abnormal ECG findings overall was 4.2%.
Conclusion: Electrocardiographic changes in athletes are frequently seen; however, a constant review of changes within abnormal or borderline parameters is recommended. It is suggested that further research studies should study the electrocardiographic changes in elite and sub-elite athletes and compare these changes considering the biological sex of the athletes to see if there are any differences.

Key words:
Football. Baseball. Basketball. Electrocardiographic. Athletes.

Prevalencia de alteraciones electrocardiográficas en deportistas élite y sub-élite

Resumen

Objetivo: El objetivo del presente estudio es evaluar la prevalencia de anormalidades electrocardiográficas que puedan poner en peligro la vida de deportistas profesionales élite y sub-élite, a partir de hallazgos normales, limítrofes y anormales en el ECG descritas en consensos internacionales.
Material y método: Estudio retrospectivo y observacional donde se analizaron los ECGs de 12 derivaciones en reposo de jugadores de élite de fútbol, béisbol y baloncesto y jugadores sub-élite de fútbol, solamente del género masculino. Los datos se recopilaron de ECGs previos a la competencia realizados por médicos afiliados al equipo en las pretemporadas 2012-2019 en deportistas de la lista activa y jugadores sub-élite. Se utilizaron las recomendaciones internacionales para la interpretación electrocardiográfica de deportistas en las variables cuantitativas para conocer las alteraciones electrocardiográficas aceptadas y evaluar la detección de anormalidades en el trazo para clasificarlas en anormal o en el límite.
Resultados: Un total de 716 ECGs fueron incluidos. Se encontraron cambios comunes en el ECG relacionados con el entrenamiento en el 63,1%; la bradicardia sinusal fue el cambio en el ECG relacionado con el entrenamiento más frecuente (47,2%). La prevalencia de lecturas limítrofes de ECG entre todos los participantes fue del 3,9%; el cambio más frecuente fue la desviación del eje a la derecha. La prevalencia de hallazgos ECG anormales en general fue del 4,2%.
Conclusiones: Los cambios electrocardiográficos en los deportistas se ven con frecuencia, sin embargo, se recomienda constante revisión de cambios dentro de parámetros anormales o en limitrófes. Se sugiere que estudios de investigación estudien los cambios electrocardiográficos en deportistas élite y sub-élite y que se comparen estos cambios teniendo en cuenta el sexo biológico de los deportistas para ver si existen diferencias.

Palabras clave:
Fútbol. Beisbol. Baloncesto. Electrocardiográficas. Deportistas.

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Introduction

Sudden Death in Sports (MSD) is a rare, unexpected tragic event occurring in a healthy person during sports practice or one hour after. It is due to natural, non-traumatic or non-violent causes. MSD represents the leading cause of death in athletes during sports[1].

Over the past decade, ECG interpretation standards have undergone several modifications to improve the accuracy of detecting life-threatening heart conditions in young athletes while limiting false-positive results. In February 2015, an international group in Seattle, Washington, updated the current recommendations for interpreting the ECG in asymptomatic athletes aged 12 to 35 years[2]. The International Criteria for the interpretation of the electrocardiogram aimed at asymptomatic athletes between 12 and 35 years of age but also included specific considerations for adolescent athletes 12-16 years of age and for those ≥30 years of age who have a higher prevalence of coronary heart disease[3].

The European Society of Cardiology guidelines recommends preparticipation screening (PPS) in the medical examination before sports practice. Among the aspects that can influence the prevalence of some alterations in an athlete's ECG are age, sex, race, type and intensity of training, and sports history[2].

The objective of our study is to determine the prevalence of electrocardiographic abnormalities that could endanger the lives of elite and sub-elite professional athletes based on normal, borderline, and abnormal findings in the ECG of players described in International Recommendations[4].

Material and method

Data collection and study population

This retrospective observational study was performed only on men elite football players, men elite baseball players, men elite basketball players, and men sub-elite football players (second division, third division, U-15, U-17, and U-20). Data was collected from pre-competition ECGs performed by team-affiliated physicians in the 2012 – 2019 preseasons on active-roster athletes and sub-elite players. Weight, fat mass percentage, and fat-free mass were measured with a bioimpedance scale. The maximum oxygen consumption was measured indirectly from a test of incremental and intermittent maximum effort on a treadmill with the protocol described by Kindermann[5], starting at 6 km/h with an incline of 5%. Each stage lasted 3 minutes with a passive rest of 30 seconds between each, and speed was increased by 2 km/h between each stage until volitional fatigue. Oxygen consumption was estimated with the formula described by Pugh[6], including the time spent during the last stage reached.

ECG Analysis

The resting 12-lead ECGs were recorded at a 10 mm/mV voltage and a paper speed of 25 mm/s. Quantitative ECG data were obtained with manual measurements by the investigators. The P-wave, PR interval, and QRS duration were measured to the nearest 2 ms from the averaged PQRST complex in lead II. If the PR interval was <120 ms in lead II, all leads were measured. The PR interval was categorized as short if <120 ms in all leads. The *R*- and *S*-wave amplitudes were measured to the nearest 1 μV as the mean of the highest amplitude in the QRS complexes. The maximum P-wave amplitude was measured in lead II. The QT intervals were corrected for heart rate (HR) (QTc) using Bazett's formula. The qualitative characteristics of each ECG were analyzed using the international recommendations for electrocardiographic interpretation in athletes[4] to detect accepted training-related ECG findings and findings classified as borderline and abnormal. The physiological cardiac adaptations to regular exercise consisted of increased QRS voltage for left ventricular hypertrophy (LVH) or right ventricular hypertrophy (RVH), incomplete right bundle branch block (RBBB), early repolarization, juvenile T-wave pattern, sinus bradycardia, sinus arrhythmia, ectopic atrial rhythm, junctional escape rhythm, first-degree atrioventricular block (AV) and Mobitz Type I second-degree AV block. For borderline electrocardiogram findings in athletes, left axis deviation, left atrial enlargement, right axis deviation, right atrial enlargement, and complete RBBB. The abnormal findings were *T* wave inversion, ST-segment depression, pathologic *Q* waves, complete left bundle branch block (LBBB), nonspecific intraventricular conduction disorder, epsilon wave, ventricular pre-excitation, long QT interval, Brugada type 1 pattern, profound sinus bradycardia (<30 bpm or sinus pauses >3 sec), profound atrioventricular block (>400 ms), Mobitz Type II second-degree AV block, third-degree AV block, atrial tachyarrhythmias, ventricular extrasystoles, and ventricular arrhythmias.

Statistical analysis

Categorical variables were presented as frequencies and percentages (%) and continuous variables as means and standard deviation (SD). The Kolmogorov-Smirnov test was performed to assess the normality of quantitative variables. An analysis of variance (ANOVA) was performed for multiple comparisons of parametric data and the Kruskal-Wallis's test for non-parametric data. When the comparisons were performed between only two groups, Student's t-test, or the Mann–Whitney test were used as applicable. SPSS version 25 (IBM Corp., Armonk, NY) was used for data analysis. Statistical significance was set at a p-value <0.05.

Results

Athlete characteristics and quantitative ECG variables

A total of 716 ECGs were included in the study, of which 103 were elite football players, 131 elite baseball players, 46 elite basketball players, and 436 sub-elite football players (second division, third division, U-15, U-17, and U-20). Athletes were aged 21.04 ± 6 years (range 14 – 45), the mean height was 178.6 ± 8.4 cm (range 158 – 228), and weight 75.7 ± 15.4 kg (range 49.7 – 131.8). Basketball players were taller and heavier than football and baseball players (Table 1). They also had the lowest fat mass percentage, with baseball players having the highest values. Aerobic capacity, expressed in absolute (l/min) and relative (ml/kg/min) values of maximal oxygen uptake volume, was significantly lower in baseball players than in the other groups of athletes. Training loads were similar in the three groups. Regarding ECG measurements, the

Table 1. Athlete and training characteristics by sport.

Characteristic	Sport			*p*-value
	Soccer (n = 103)	Baseball (n = 131)	Basketball (n = 46)	
Age, y	25.9 ± 4.4	27.79 ± 5.4	28.5 ± 4.3	<0.001
Height, cm	178.4 ± 6.7	182.2 ± 2.3	196.1 ± 10.6	<0.001
Weight, kg	75.3 ± 7.6	96.2 ± 12.5	98.4 ± 13.9	<0.001
BMI, kg/m²	23.6 ± 1.6	28.9 ± 3.1	25.4 ± 1.8	<0.001
fat-free mass, kg	65.2 ± 6.9	77.6 ± 8.0	87.9 ± 13.1	<0.001
Fat mas, %	13.2 ± 3.1	18.8 ± 5.9	10.6 ± 3	<0.001
Absolute VO_2, l/min	4.3 ± 0.4	4.1 ± 0.5	4.7 ± 0.6	<0.001
Relative VO_2, ml/kg/min	54.1 ± 3	45.1 ± 5.6	48.5 ± 5.4	<0.001
Training				
- Duration, min	134.5 ± 34.2	135.6 ± 69.6	128.6 ± 32.3	0.328
- Frequency, days per week	1.3 ± 0.5	1.7 ± 0.4	1.6 ± 0.4	0.174
- Sessions, per day	5.8 ± 0.6	6.3 ± 0.7	5.4 ± 1.1	0.503

BMI, body mass index; VO_{2max}- maximal oxygen consumption. Mean ± SD.

Table 2. Quantitative ECG variables in elite soccer, baseball, and basketball players.

Variable	Sport			*p*-value
	Soccer (n = 103)	Baseball (n = 131)	Basketball (n = 46)	
Heart rate, bpm	56.17 ± 9.2	63.9 ± 10.7	54.8 ± 11.5	<0.001
PR interval, ms	171 ± 25	164 ± 25	181 ± 33	<0.001
QRS duration, ms	99 ± 81	92 ± 15	92 ± 14	0.631
QTc interval, ms	402 ± 33	385 ± 29	395 ± 31	<0.001

Mean ± SD.

mean heart rate at rest was 60.6 ± 10 bpm, the PR interval 163 ± 25.5 ms, the QRS duration 93.2 ± 38.4 ms, and the QTc interval 398.9 ± 29.6. We observed significant differences in heart rate, PR, and QTc interval among the three elite groups (Table 2).

Training-related ECG findings

Figures 1 and 2 show the prevalence of ECG findings classified as training-related, borderline, or abnormal in elite and sub-elite players. Overall, the ECG was considered normal in 91.6%, with common training-related ECG changes found in 63.1%, 16% had two or more findings. Sinus bradycardia was the most prevalent training-related ECG finding at rest (47.2%), followed by incomplete right bundle branch block (8.2%); both were more frequent in basketball players. The lowest heart rate was 35 bpm, seen in two elite football players. There were differences between elite and sub-elite ECG findings; for example, increased QRS voltage for LVH or RVH and early repolarization were more frequently observed in sub-elite than in elite players. Otherwise, first-degree AV block was seen in 6% of elite players versus 0% in the sub-elite group (Tables 3 and 4). The most prevalent training-related ECG finding with effort was incomplete RBBB (2.1%), followed by early repolarization (0.3%).

Figure 1. Prevalence of training-related, borderline, and abnormal ECG findings in elite football, baseball, and basketball players.

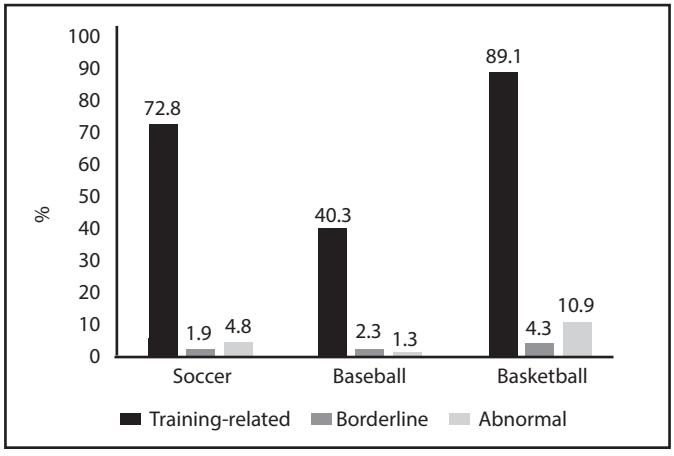

Figure 2. Prevalence of training-related, borderline, and abnormal ECG findings in sub-elite football players.

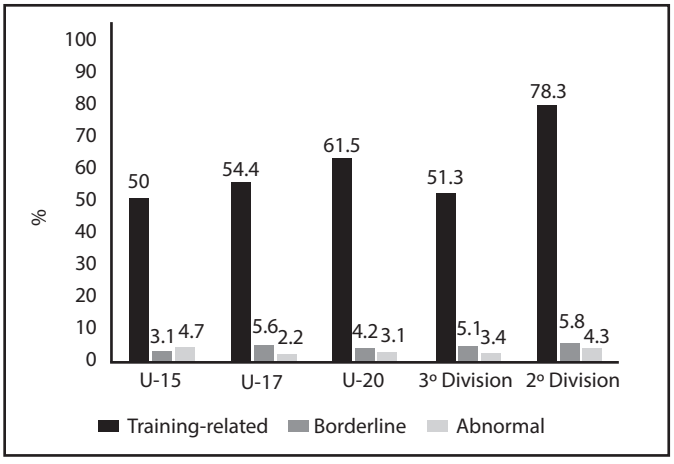

Table 3. Training-Related ECG Findings in elite soccer, baseball, and basketball players.

Finding	Sport No. (%)		
	Soccer (n = 103)	Baseball (n = 131)	Basketball (n = 46)
Increased QRS voltage for LVH or RVH	8 (7.7)	4 (3)	5 (10.8)
Incomplete RBBB	6 (5.8)	11 (8.3)	6 (13)
Early repolarization	0	7 (5.3)	4 (8.6)
T wave inversion V1-V3 < age 16	0	0	0
Sinus bradycardia	66 (64)	49 (37.4)	37 (80.4)
Ectopic atrial or junctional rhythm	1 (0.9)	0	1 (2.1)
1º AV block	4 (3.8)	5 (3.8)	8 (17.3)

LVH: left ventricular hypertrophy; RVH: right ventricular hypertrophy; RBBB: right bundle branch block; AV: atrioventricular.

Table 4. Training-Related ECG Findings in sub-elite soccer players.

Finding	Classification No. (%)				
	U-15 (n = 64)	U-17 (n = 90)	U-20 (n = 96)	3rd Division (n = 117)	2nd Division (n = 69)
Increased QRS voltage for LVH or RVH	2 (3.1)	12 (13.3)	13 (13.5)	16 (13.6)	14 (20.2)
Incomplete RBBB	5 (7.8)	7 (7.7)	15 (15.6)	14 (11.9)	6 (8.6)
Early repolarization	11 (17.1)	3 (3.3)	8 (8.3)	8 (6.8)	11 (15.9)
T wave inversion V1-V3 < age 16	1 (1.5)	0	0	0	0
Sinus bradycardia	24 (37.5)	36 (40)	44 (45.8)	35 (29.9)	44 (63.7)
Ectopic atrial or junctional rhythm	0	0	0	0	0
1º AV block	0	0	0	0	0

U-15: under 15 years; U-17: under 17 years; U-20: under 20 years; LVH: left ventricular hypertrophy; RVH: right ventricular hypertrophy; RBBB: right bundle branch block; AV: atrioventricular.

Borderline and abnormal ECG findings

The prevalence of borderline ECG readings among all the participants was 3.9%. The most frequent finding was right axis deviation, mostly in sub-elite football players (3.4% *vs*. elite, 1.07%). The prevalence of abnormal ECG findings overall was 4.2%, of which 76% of the cases are represented by *T* wave inversion (3.2%) followed by ventricular pre-excitation (0.5%). However, the only abnormality in the sub-elite group was *T* wave inversion. Further findings are provided in Tables 5 and 6.

Table 5. Borderline and Abnormal ECG findings in elite soccer, baseball, and basketball players.

Finding	Sport No. (%)		
	Soccer n = 103	Baseball n = 131	Basketball (n = 46)
Borderline			
Left axis deviation	1 (0.9)	1 (0.7)	1 (2.1)
Left atrial enlargement	0	0	0
Right axis deviation	1 (0.9)	2 (1.5)	0
Right atrial deviation	0	0	1 (2.1)
Right atrial enlargement	0	0	0
Complete RBBB	0	0	0
Abnormal			
T wave inversion	5 (4.5)	1 (0.7)	2 (4.3)
Pathologic *Q* waves	1 (0.9)	0	0
Complete LBBB		0	0
Ventricular pre-excitation	1 (0.9)	0	3 (6.5)
Prolonged QT interval	1 (0.9)	1 (0.7)	0

RBBB: right bundle branch block; LBBB: left bundle branch block.

Table 6. Borderline and abnormal ECG findings in sub-elite soccer players.

Finding	Classification No. (%)				
	U-15 (n = 64)	U-17 (n = 90)	U-20 (n = 96)	3rd Division (n = 117)	2nd Division (n = 69)
Borderline					
Left axis deviation	0	0	0	0	1 (1.4)
Left atrial enlargement	0	0	0	0	0
Right axis deviation	2 (3.1)	3 (4.6)	3 (3.1)	3 (2.5)	2 (2.8)
Right atrial deviation	0	0	0	0	0
Right atrial enlargement	0	0	0	1 (0.8)	0
Complete RBBB	0	2 (3.1)	1 (1)	2 (1.7)	1 (1.4)
Abnormal					
T wave inversion	3 (4.6)	2 (3.1)	3 (3.1)	4 (3.4)	3 (4.3)
Pathologic *Q* waves	0	0	0	0	0
Complete LBBB	0	0	0	0	0
Ventricular pre-excitation	0	0	0	0	0
Prolonged QT interval	0	0	0	0	0

U-15: under 15 years; U-17: under 17 years; U-20: under 20 years; RBBB: right bundle branch block; LBBB: left bundle branch block.

Discussion

Preparticipation screening (PPS) in athletes is important to assess their physical condition and avoid complications. In the classifications used to evaluate electrocardiograms by expert doctors, we have three types of findings: normal, abnormal, and borderline[2]. It is important to classify each athlete to avoid one of the greatest fears in sports, sudden death.

In our study, the first thing we compared were the demographics: weight, height, and BMI. Our study found that basketball players were taller and heavier than football and baseball players. They also had the lowest fat mass percentage, with baseball players having the highest values. A Stanford study involving 641 college athletes compared teams from different sports and found that athletes who play basketball are taller and heavier but have a lower BMI[7]. This study corroborates that, athletes who practice basketball are taller than athletes of any other sports and have a lower fat mass and BMI. Thus, the type of sport practiced by athletes greatly influences the physical characteristics they need.

The maximal oxygen uptake or aerobic capacity (VO_{2max}), which is affected o related to body weight and expressed in absolute (l/min) and relative (ml/kg/min) values of maximal oxygen uptake volume, was significantly lower in baseball players. There are no studies that compare aerobic capacity between athletes from different sports. We recommend further research in this area of opportunity.

Regarding common ECG findings, we found that sinus bradycardia was the most prevalent training-related ECG change at rest (47.2%), followed by an incomplete right bundle branch block (8.2%). Both were more frequent in basketball players. In a study of 40 runners, 25 of the participants presented sinus bradycardia as the most frequent training-related finding, followed by LVH by voltage criteria in 12 (30%) and early repolarization in 11 (20.4%)[8]. These were also found in Brunei, a cross-sectional descriptive study of 100 athletes, where it was found that the most frequent changes related to training were, first, sinus bradycardia (29%), followed by J-point elevation (18%), and last, right atrial enlargement (7%)[9]. In a study by Beale *et al.,* 43 athletes participated, the most frequent finding was sinus bradycardia (97.6%), followed by left ventricular hypertrophy (65%), and early repolarization (97.6%)[10]. In another study of 519 NBA-affiliated basketball players, early repolarization was the most prevalent training-related ECG finding. It was present in 362 athletes (72.6%)[11]. In Abubakar's study, the only normal finding due to frequent training was sinus bradycardia in 29%[11]. As seen in the previously mentioned studies, the most frequent findings ranged from sinus bradycardia and early repolarization. These changes can be because systematic sports training can produce chronic changes and/or cardiovascular adaptations, defined as "athletic heart syndrome," with the antecedent of prolonged and intense systemic sports practice and required physical performance[12].

Borderline ECG among all our participants was 3.9%, and the most frequent change was right axis deviation, mostly in sub-elite football players (sub-elite, 3.4% *vs.* elite, 1.07%). Kaleta found right atrial enlargement higher at 42.5%, followed by left atrial enlargement at 37.5%[9]. In our study, borderline findings existed in a very low percentage of athletes, and the most frequent was atrial hypertrophy (2.6%), followed by complete right branch block (0.5%)[13]. As seen in previous studies, the most frequent borderline ECG findings are left and right atrial enlargement with 13.3 and 8.9%, respectively[11]. In the study by Beale, the most frequent finding was left axis deviation (4.7%), followed by right atrial enlargement (2.3%)[10]. The most frequent borderline findings found in the different studies were very similar; however, atrial enlargements are more prevalent than in our study, in which axis deviation predominated. We believe that there should be extensive surveillance of these types of patients if they present symptoms because the findings on the ECG are not normal and could affect their physical condition[12].

Finally, the overall prevalence of abnormal ECG findings was 4.2%, of which 76% represented T wave inversion (3.2%), followed by ventricular pre-excitation (0.5%). Like our study, the most frequent training-unrelated ECG change in Beale *et al.*[10] was *T*-wave changes with 4.6%. In the same way, in Waase's study, the most prevalent abnormal finding was the *T* wave inversion with 6.2%[11]. However, Gademan's study found that the most common finding was ST-segment depression. A finding different from all the studies was a pathological *Q* wave in a low percentage[7]. All these studies have in common the findings in changes in the *T* wave; however, Gademan calls our attention to the appearance of a pathological *Q* wave. Additional studies should be performed on this type of athlete regardless of their medical history, even if they do not have symptoms. An initially abnormal ECG may have a predictive value that requires careful follow-up and monitoring due to the possibility of developing heart disease later[12].

Conclusions

Electrocardiographic changes in athletes are frequent; however, constant tracking of abnormal parameters or borderline changes is recommended. The most common electrocardiographic changes were those classified as normal related to physical activity, finding sinus bradycardia first, followed by incomplete right bundle branch block, which was more prevalent in basketball players. On the other hand, the most frequent borderline change in the participants was right axis deviation seen in sub-elite players, and the most prevalent abnormal change was *T* wave inversion. Some of the limitations of our study were that there were only men, and the predominant sport was football. This limitation occurred because we had the athletes' data since 2016 with more information about elite and sub-elite categories. Another limitation of this study is that the athletes who had an ECG abnormality were not followed to assess whether there was an outcome to determine its validity as a finding. It is suggested that further research should study the electrocardiographic changes in elite and sub-elite athletes and compare these changes considering the biological sex of the athletes to see if there is any difference.

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Conflict of interest

The authors do not declare a conflict of interest.

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