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Benign Prognosis of Early Repolarization Pattern in Elite Athletes After a Long Follow-Up

Ricard Serra-Grima [1], Maite Doñate [1], Jesús Álvarez-García [1], Ana Barradas-Pires [1], Andreu Ferrero [2], Lidia Carballeira [1], Teresa Puig [2], Enrique Rodríguez [1], Juan Cinca [1]

[1] Department of Cardiology, Hospital de la Santa Creu i Sant Pau, IIb-Sant Pau, Universitat Autónoma de Barcelona, Barcelona, Spain

[2] Department of Epidemiology and Health, Hospital de la Santa Creu i Sant Pau, Universitat Autónoma de Barcelona, Barcelona, Spain

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Address for correspondence:

Jesús Álvarez-García, MD,

Department of Cardiology

Hospital de la Santa Creu i Sant Pau

St. Antoni M. Claret 167, 08025, Barcelona, Spain

Phone: +34935565940, fax: +34935565603, e-mal: jalvarezg@santpau.cat

ABSTRACT

Background Analyze the prevalence, clinical characteristics, and long-term outcome of early repolarization pattern (ERP) in elite athletes during professional activity and after retirement. ERP is considered a benign variant of the ECG, more frequent in athletes. However, prospective studies suggested that ERP is associated with an increased risk of sudden cardiac death (SCD).

Methods and Results A cohort of 299 elite athletes recruited between 1960-1999 was retrospectively analyzed. Athletes were eligible if they had participated for at least six consecutive months in high-competition and retired for a minimum of five years before inclusion. Clinical data and ECG were abstracted from the clinical records using a questionnaire and outcomes after a mean follow-up of 24 years were registered. Among the 299 athletes, 66% were men with a mean age of 20 (SD 6.4) years. ERP was found in 31.4% of participants and it was located in lateral ECG leads in 57.4% of cases, in inferior in 6.4%, and in both leads in the remaining 36.2%. After retirement ERP still persisted in 21.1% of athletes. Predictive factors for the persistence were: Sokolov-Lyon index ≥ 3,5 mV (OR 4.35; CI95% 1.43-13.24; p=0.010), sinus bradycardia (OR 2.56; CI95% 1.09-5.99; p=0.031), and presence of ERP during the sportive career (OR 20.35; CI95% 8.54-48.51; p<0.001). After a mean follow-up of 24 years no episodes of SCD occurred.

Conclusion A third part of elite athletes presented ERP. This pattern persisted in most of participants after retirement and was not associated with fatal events after a long follow-up.

Keywords Early repolarization pattern, athletes, electrocardiogram, sudden cardiac death.

INTRODUCTION

Early repolarization pattern (ERP) is defined as a broad positive deflection originating from an elevated J-point in inferior or lateral ECG leads (1). This ECG pattern has been historically considered a normal variant in the general population (2), being more prevalent in males, African-Americans, and in young trained athletes especially those engaged in endurance disciplines (3, 4). However, emerging data from case-control (5, 6) and prospective cohort (7) studies suggested that ERP in the inferior ECG leads is associated with an increased risk of sudden cardiac death (SCD). Although SCD is relatively rare in athletes, an association between ERP in inferior leads and SCD has been recently reported (8). Moreover, recent refined analyses of the morphology of ST-segment following the early repolarization waveforms have afforded new light in the stratification of individuals at higher risk of arrhythmic death. Indeed, ascending/upsloping ST-segments identified individuals with benign prognosis whereas horizontal/descending ST variant was associated with a high risk of arrhythmic death (9-11). Although almost 50% of cases of SCD in athletes there were not an identifiable cardiac disorder (12), studies in patients with acute myocardial infarction have shown that the presence of horizontal/descending ST-segment in the ECG recorded before the ischemic event increased the risk for occurrence of ventricular fibrillation (13, 14). The magnitude of ERP and the intensity of the training are closely related (15), but the factors determining the persistence of ERP in athletes after cessation of high-level training are not well known. Therefore, the aim of our study was to analyze the prevalence and clinical characteristics of ERP in active athletes and the very long-term prognosis after their retirement.

METHODS

Study population

This is a retrospective longitudinal study which included 299 Caucasian high level competition athletes referred to the Health and Sport Unit of Consell Català de l´Esport of Barcelona City, Medical Service of Barcelona Football Club, and High Performance Center at Sant Cugat del Vallés, Barcelona, between 1960 to 1999. Athletes were included if they fulfilled the following criteria: a) participation in elite competitions while in active training. We defined competitive athletes and official sports competition as previously defined by the Study Group of Sports Cardiology of the European Society of Cardiology (16); b) maintenance of a high level of competition training for at least six consecutive months, and c) retirement from intensive training for a minimum of five years before inclusion in the study. This study was approved by our institutional review committee and written consent was obtained from all participants.

Clinical variables

Demographic and clinical baseline information was abstracted from the clinical records using a structured questionnaire. This included the type of sport performed, the number of hours of weekly training during competitions periods, and the number of years participating in high level competition. The level of training during the high competition period was classified dichotomously according to a 12 weekly hours training cut-off. A resting 12-lead ECG was obtained during the baseline visit.

In the follow-up visit, we recorded a complete clinical history, ECG, cardiovascular events (SCD, myocardial infarction, and stroke), number of years since retirement from high competition, and information on current physical activity categorized as high >5 hours a week; low <5 hours a week. Follow-up period was calculated as the time (years) elapsed between the baseline and the follow-up visit.

ECG variables

The presence of ERP and its morphologic characteristics were stated according to the work of Tikkanen et al (9). ERP is defined by upright deviation of the J-point of at least 1 mm (0.1 mV) from baseline appearing either as QRS complex slurring (a smooth transition from the QRS to the ST segment), QRS complex notching (a positive J deflection inscribed on the S wave), or as discrete QRS complex contour (ERP after signal return to baseline). These patterns could be observe in the inferior ECG leads (II, III and aVF), lateral leads (I and aVL, V4-V6) or in both groups of leads. ST-segment patterns after the J point were coded as: (1) horizontal/descending or (2) upsloping/rapidly ascending. The upsloping/rapidly ascending ST segment was defined as ≥0.1 mV elevation of ST segment within 100 ms after the J point or a persistently elevated ST segment of ≥0.1 mV throughout the ST segment. Horizontal/descending type was defined as <0.1 mV elevation of the ST segment within 100 ms after the J point. The baseline was defined as the level between 2 T-P intervals. Sinus bradycardia was categorized as: light (51-60 bpm); moderate (41-50 bpm); and severe (≤40 bpm) (17). QT interval duration was corrected according to the Bazett´s formula. Left bundle branch block (LBBB) was defined by a prolonged QRS duration of 120 ms or more associated with broad, notched R wave without q waves in leads I, aVL, and V6 and a rS pattern in lead V1. Right BBB (RBBB) was characterized by prolonged QRS duration of 120 ms or more associated with an R, rSR´, or qR wave in lead V1; wide, slurred S waves in leads I, aVL, V5, and V6 ; and a wide terminal r wave in aVR. The presence of left ventricular (LV) hypertrophy at the ECG was defined by a Sokolov-Lyon index ≥ 3,5 mV.

Echocardiographic variables

Since echocardiographic examination was not feasible at the beginning of the inclusion period (1960) and was not routinely performed in athletes thereafter, we only include in this study the recordings obtained in 64% of participants during the follow-up visit.

Data analysis

Descriptive analyses were performed at the first step. Categorical variables were described by frequencies and percentages. Statistical differences were analyzed using a 2x2 table test and the χ^2 test. Continuous variables were described by the mean and standard deviation and statistical differences were analyzed using the student's t test in the case of a normal distribution. To identify independent predictors of ERP in the follow-up visit, a multivariable logistic regression model was constructed, adjusting for the covariates statistically significant at the univariate analysis (p value less than 0.20 as a criterion of entry into multivariate analysis). Additionally, the final model was adjusted for those variables categorized as clinically relevant. Significant predictors of ERP were expressed in terms of odds ratio and 95% confidence intervals (CI). To assess the predictive ability of our model, we calculated the area under the receiver operating characteristics curve (ROC) following a nonparametric distribution assumption. A p value of less than 0.05 was considered statistically significant. Data were analyzed using the statistical package SPSS for Windows (IBM, SPSS Statistics, 21 version).

RESULTS

Clinical characteristics

Among the 299 elite athletes included in the study, 94 (31.4%) presented ERP on admission. As shown in Table 1, athletes with and without ERP showed comparable demographic profile except for a higher incidence of males in the former group. Likewise, both groups of athletes showed comparable distribution of competition categories and similar volume of physical training. Our study participants had been in the elite sport over 3 years on average and most of them trained more than 12 hours a week. The sports spectrum was very broad, but Athletics were practiced by about 45% of participants.

ECG

As shown in Table 2, the presence of ERP was significantly associated with sinus bradycardia, criteria of LV hypertrophy, and a longer QRS complex duration. However, there were not differences in the corrected QTc interval and the presence of RBBB. The ERP was observed in lateral leads in 57.4% of cases, in inferior leads in 6.4%, and in both regions in 36.2%. The large majority of cases presented an ascending/upsloping ST-segment with a J-point elevation between 0.1 to 0.2 mV from baseline. In the group of ERP, the pattern of the QRS morphology was discrete in the 41.2% of cases and slurred and notched in about 30%. There were 2 cases of horizontal/descending ST-segment, more apparent in the inferior leads. Figure 1 illustrates a typical example of ERP with ascending/upsloping ST-segment.

Follow-up

The mean follow-up was 24 years (SD 7.6) with a minimum and a maximum of 10 and 47 years respectively. Mean age of participants at the second visit was 45 years (SD 9.3, interquartile range 24-75). After competition retirement, 30% of individuals of the non-ERP group and 50% of those with ERP continued to maintain a significant level of training (>5 hours/week) (28.5% vs 47.6%, p 0.004). As shown in Table 3, the prevalence of cardiovascular risk factors and cardiovascular events in our series was very low. Non-fatal myocardial infarction occurred in two athletes and none of the participants died. We observed a prevalence of the ERP in 63 out of 299 athletes (21.1%), mainly located at the lateral (50.8%) and inferior-lateral leads (47.6%). The presence of bradycardia was significantly higher in the ERP group (71.4% vs. 41.9%, $p<0.001$). Among the 63 athletes who presented RP in the follow-up, 51 already showed this pattern in the time of enrollment (persistent ERP), while in 12 of them this pattern appeared de novo. Supplementary Table 1 summarizes the demographic, clinical, and electrocardiographic characteristics of athletes with these three ERP forms. The total number of competitions and medals won in national and international championships by the athletes included in our study are summarized in Supplementary Table 2.

The echocardiographic examination was performed in 64% of cases during the follow-up visit. Athletes with or without ERP showed comparable LV ejection fraction (74±10 vs. 71±9%), thickness of LV septum (9±1 vs. 9±2 mm), thickness of posterior LV wall (9±1 vs. 8±2 mm), and left atrial diameter (33±5 vs. 32±6 mm). The LV diameter was larger in the ERP group (50±6 vs. 48±5 mm, $p <0.05$).

The multivariate analysis showed that the predictors of current ERP were a Sokolov-Lyon index ≥ 3,5 mV, sinus bradycardia at second visit and ERP during elite activity (Table 4). However, male sex and the volume of training either during high level competition or after retirement was not a significant predictor. Figure 2 shows the ROC curve of the model to predict the presence of ERP in the follow-up ECG (AUC 0.89; CI 95% 0.85-0.94, $p < 0.001$).

DISCUSSION

Main findings

This study shows that one third of elite athletes present ERP during their active competition life and this ECG pattern is associated with a benign prognosis after a mean follow-up period of 24 years. In 97.5% of cases the ERP was associated with ascending/upsloping ST-segment and only 2.5% presented horizontal/descending ST-segment pattern. Moreover, the study denotes that the ERP persists after professional retirement in a high proportion of cases.

Prevalence of ERP and related factors

The prevalence of ERP in the general population is largely variable as it is influenced among others by race, age, level of physical activity, characteristics of the QRS complex and by the definition of ERP itself (18). In a recent meta-analysis based on 7 prospective observational cohort studies and on 3 case-control studies, the prevalence of ERP varied from 0.9% to 31% (19). Applying a stricter criterion, the prevalence of ERP was 18.6% in a series of 5069 participants of the CARDIA cohort with a mean age of 25 years and black race in 40% (20). The prevalence of ERP among athletes is higher than that observed in the general population. In our elite athletes the ERP was present in 31% of cases and this prevalence was similar to that observed in a cohort of 503 athletes recruited between 2000-2010 at University of Miami (3), and also comparable with a study on 879 colleague athletes registered between 2006 and 2010 at Harvard University (15). In the multivariate analysis, the predictive factors for the presence of ERP after competition retirement were a Sokolov-Lyon index ≥ 3.5 mV, sinus bradycardia, and presence of ERP during the sporting career. The most common type of sportive activity associated with ERP in our series was athletics (45%). However, this association was not statistically significant because of the wide spectrum of modalities, intensity of training, and physiological characteristics of the exercise (isovolumetric or isotonic) performed by our athletes.

The mechanism by which intensive physical training could favor the development of ERP is apparently related to a concomitant increased vagal tone. Indeed, it has been extensively documented that sinus bradycardia is one of the most prevailing electrophysiological feature in active athletes (21), and that the degree of sinus bradycardia depends on intensity of physical training (22). Parasympathetic modulation increases regional electrophysiological differences and repolarization dispersion, which might result in an elevation of the ST and J point and prominent T waves (23). Experimental studies in dogs have raised the hypothesis that ERP is caused by a transmural voltage gradient created by a spike-and-dome action potential which is present in the epicardium but absent in the endocardium (24). The latter is mediated by transitory outward potassium current (Ito). This hypothesis is supported by the observation of mutations affecting the potassium currents in patients with ERP suffering ventricular arrhythmias (25, 26)

Prognosis of ERP

Studies conducted in the general population have reported cases of SCD secondary to idiopathic ventricular fibrillation in individuals with ERP (5, 6). More recently, in a meta-analysis based on seven prospective observational cohort studies and 3 case-control studies assessing the association between the ERP and risk for cardiac death, arrhythmia death, or all-cause death, showed that ERP was associated with increased risk and a low intermediate absolute incidence rate of arrhythmia death (19).

In these reports the presence of J-point elevation > 0.1 mV in the inferior leads and the notching configuration was associated with an increased risk for arrhythmia death.

The estimated annual incidence of SCD in athletes is very low (1/75,000 to 1/200,000) (27, 28, 29). In a case-control study including 21 athletes with SCD and 365 healthy athletes with previous ECG screening, the J wave and/or QRS slurring was found more frequently among athletes with SCD than in controls (8). However, in a prospective study in a cohort of 503 athletes with a 30% of ERP prevalence, there were no cases of family history of SCD and there were no cases of SCD or symptomatic ventricular tachyarrhythmia during the 10 years period of ECG screening (3). Likewise, in a cross-sectional cohort of 879 newly matriculated student athletes with ERP mainly of the inferior subtype, there were no cases of SCD and unexplained syncope or hospitalization for cardiovascular causes after a mean follow-up of about 21 months (15). In these series the incidence of ERP increased after a load period of intensive physical training. A major contribution in risk stratification in subjects with ERP was the observation of an association between the morphology of the ST-segment and the hazard ratio of arrhythmic death (9). Indeed, young athletes with horizontal/descending ST-segment had an increased HR of arrhythmic death than subjects with ascending/upsloping ST-segment pattern. These findings were later confirmed in case-control series in the general population (10, 11). Our study supports the benign prognosis of ERP with upsloping ST-segment in elite athletes during the largest follow-up period ever reported (mean follow-up of 24 years).

In summary, this retrospective cohort of 299 elite athletes of Caucasian ethnicity shows that ERP was present in one third of the participants and that this ECG pattern was not associated with fatal events after a mean follow-up of about 24 years. In 97.5% of cases the ERP was associated with ascending/upsloping ST-segment and only 2.5% presented horizontal/descending ST-segment pattern. The ERP persisted in most of cases after sportive retirement and was highly associated with sinus bradycardia. The predictive factors for the presence of ERP after the retirement were a Sokolov-Lyon index ≥ 3,5 mV, current sinus bradycardia, and presence of ERP during the elite activity.

Study Limitations

The sample size of our cohort was relatively modest, but the strength of the data presented here is founded by the very long follow-up period of the study. All of our participants were of Caucasian ethnicity thus present data can not be extrapolated to other races since a higher association of ERP with African ethnicity has been recognized (3, 4).

Echocardiographic studies were not feasible at the early beginning of the inclusion period, and were not routinely performed thereafter. However, the recordings obtained during the follow-up visit in 64% of athletes suggested that the ERP is not associated with underlying structural heart disease, as has been previously recognized (15).

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FIGURE LEGENDS

Figure 1: Disappearance of early repolarization pattern after a follow-up of 17 years

Panel A shows an illustrative example of an ascending/upsloping ST segment type of early repolarization pattern, in the lateral ECG leads of a marathon runner in 1983. **Panel B** shows the ECG of the same athlete, five years after retirement from the practice of elite sport.

Figure 2: Receiver operating characteristics curve of the model

The graphic shows the ROC curve of the model predicting the presence of ERP in the follow-up ECG (AUC 0.89; CI 95% 0.85-0.94, p <0.001).

Table 1: Demographic and sportive characteristics of 299 elite athletes with and without early repolarization pattern at study inclusion

	No ERP (205)	ERP (94)	p value	ECG Localization of ERP			p value
				Inferior (6)	Lateral (54)	Inferolateral (34)	
Age, years	20,1±6,4	20,5±6,4	ns	21,3±9,2	20,3±6,5	20,7±5,8	ns
Male, %	60,5	77,7	0,004	66,7	75,9	82,4	0,027
Weight, Kg	63,7±12,8	61,9±10,9	ns	56,2±9,9	61,0±10,7	64,4±10,9	ns
Height, cm	170,7±11,1	170,1±9,2	ns	166,2±11,8	170,1±9,3	171,0±8,7	Ns
BMI, Kg/m^2	21,1±2,6	21,0±2,2	ns	19,8±1,7	20,8±2,2	21,5±2,3	Ns
<u>Sportive Category</u>							
Athletics, %	45,4	44,7		50,0	50,0	35,3	
Swimming, %	13,2	16,0	ns	16,7	9,3	26,5	ns
Basketball, %	6,8	4,3		0,0	5,6	2,9	
Others, %	34,6	35,1		33,3	35,2	35,3	
<u>Volume of Training</u>							
High (>12 h/w), %	79,5	84,9	ns	100	86	80,6	ns
Low (<12 h/w), %	20,5	15,1		0	14	19,6	
Time on High-level Competition, y	3,5±5,1	3,8±4,8	ns	6,3±9,9	3,0±4,2	4,6±4,4	ns

***Abbreviations: ERP = early repolarization pattern; BMI = body mass index; BSA = body surface area; Kgs = kilograms; m = meters; h = hour; w = week; y = year; ns = no significance.**

Table 2: ECG data of 299 elite athletes with and without early repolarization pattern at study inclusion

	No ERP (205)	ERP (94)	p value	ECG Localization of ERP			p value
				Inferior (6)	Lateral (54)	Inferolateral (34)	
HR, bpm	50,5±24,8	47,0±19,5	ns	42,7±21,7	46,8±20,6	47,9±17,9	ns
Sinus Bradycardia, %	63,9	87,2	<0,001	66,7	85,2	94,1	<0,001
Light	38,6	39,5		33,3	34,1	48,4	
Moderate	36,4	43,2		50	50	32,3	
Severe	25	17,3		16,7	15,9	19,4	
Any J-point□0.2mV, %	-	8,2	-	0	6,3	12,9	<0,001
QRS pattern, %							
Discrete	-	41,2	-	50	47,9	29	<0,001
Slurred	-	29,4		33,3	22,9	38,7	
Notched		29,4		16,7	29,2	32,3	
QRS duration, ms	82±8	92±8	<0,001	90±6	91±8	95±8	ns
ST-segment pattern, %							
Ascending/upsloping	-	97,5	-	83,3	97,7	100	0,059
Horizontal/descending	-	2,5		16,7	2,3	0	
Sokolov-Lyon >3.5 mV, %	10,2	40,5	<0,001	33,3	38,3	45,2	<0,001
QT, ms	336,8±145,1	260,9±136,4	ns	348,3±171,4	352,9±143,0	375,3±121,9	ns
QTc, ms	331,3±142,5	337,1±126,8	ns	320,3±157,1	331,9±134,1	348,2±112,2	ns
RBBB, %	4,4	6,4	ns	0	7,4	5,9	ns

***Abbreviations: ERP = early repolarization pattern; HR = heart rate; bpm = beats per minute; ms = milliseconds; mV = millivolts; RBBB = right bundle branch block; ns = no significance**

Table 3: Clinical and sportive characteristics of 299 elite athletes after a mean follow-up of 24 years

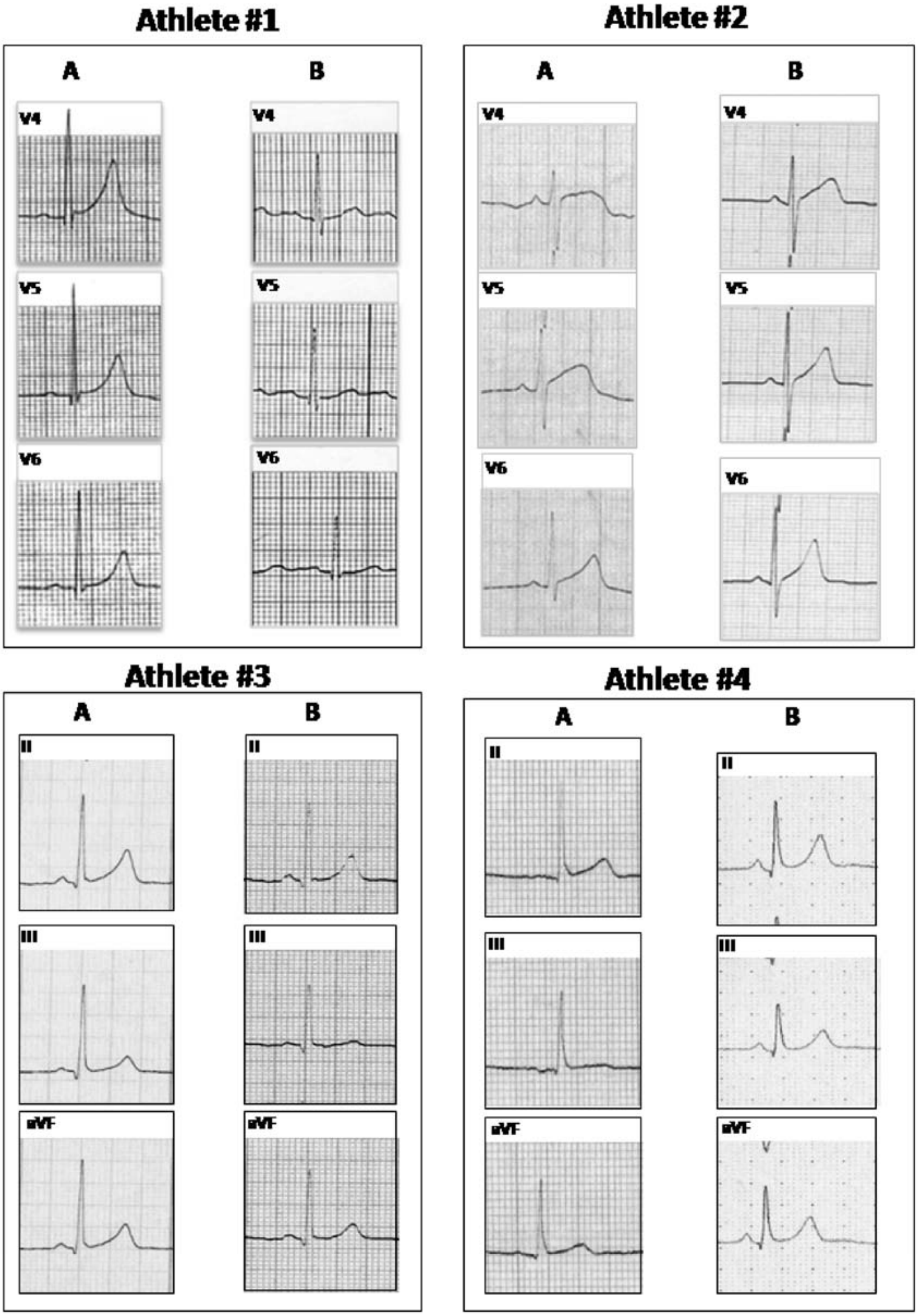
	ERP (63)	No ERP (236)	p value	ECG Localization of ERP			p value
				Inferior (1)	Lateral (32)	Inferolateral (30)	
Age, years	43,7±9,75	45,0±7,5	ns	55,00	43,12±7,64	43,87±7,28	ns
Male, %	87,3	60,2	ns	100	84,4	90,0	ns
Weight, Kg	73,7±72,1	72,1±14,4	ns	55,00	73,91±10,95	74,10±10,32	ns
BMI, Kg/m^2	23,5±2,8	23,5±3,5	ns	19,00	23,31±3,05	23,93±2,53	ns
Sinus Bradycardia, %	71,4	41,9	0,000	100	68,8	73,3	ns
<u>Sportive Category %</u>							
Athletics	46	45,3	ns	100	50,0	40,0	ns
Swimming,	14,3	13,6		0,0	15,6	13,3	
Basketball	3,2	6,8		0,0	6,2	3,2	
Others	36,5	34,3		0,0	341,4	40,0	
<u>Volume of Training %</u>							
High (>5 h/w)	47,6	28,5	0,004	100	46,9	46,7	ns
Low (<5 h/w)	52,4	71,5		0	53,1	53,3	
Smoker, %	3.2	17,5	0,041	0,00	6,2	0,00	ns
High Blood Pressure, %	1,6	8,9	0,048	0,00	0,00	3,3	ns
Dyslipidemia, %	17,5	12,3	ns	0,00	18,8	16,7	ns
Diabetes, %	0,0	0,9	ns	0,00	0,00	0,00	ns
<u>CV events %</u>							
Myocardial infarction	0,0	0,9	ns	0,00	0,00	0,00	ns
Stroke	0,0	0,9	ns	0,00	0,00	0,00	ns
NSMVT	3,2	1,7	ns	0,00	3,1	3,3	ns
Time on High-Level Competition, y	13,9±5,7	11,9±5,9	0,022	22,0±0,0	12,9±5,4	14,6±5,9	ns
Leaving High Level, y	13,2±6,4	16,5±8,5	0,004	16,0±0,0	13,2±6,6	13,1±6,4	ns
Study Follow-up, y	22,4±6,2	24,7±7.9	0,030	32,0±0,0	22,1±6,7	23,4±5,6	ns

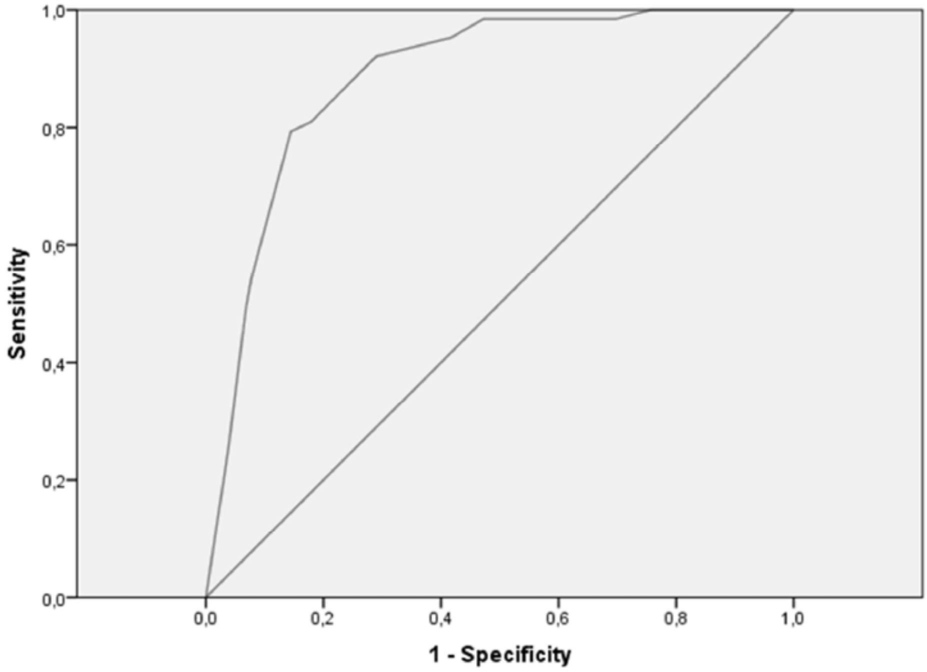
***Abbreviations: ERP = early repolarization pattern; BMI = body mass index; BSA = body surface area; Kgs = kilograms; m = meters; HR = heart rate; bpm = beats per minute; ms = milliseconds; h = hour; w = week; y = years; NSMVT = non-sustained monomorphic ventricular tachycardia.**

Supplementary Table 1: Demographic, clinical, and electrocardiographic characteristics of athletes with persistent, non-persistent, and de novo early repolarization pattern after a follow-up period of 24 years.

	Persistent ERP (51)	Non-persistent ERP (43)	De novo ERP (12)	p value
Age, y	43,7±7,0	41,2±8,9	43,7±6,9	ns
Male, %	86,3	67,4	91,7	0,043
Weight, Kg	73,5±11,0	67,7±13,4	74,5±10,2	0,043
BMI, Kg/m2	23,6±3,0	22,5±2,9	22,9±1,9	ns
Sinus Bradycardia, %	68,6	46,5	83,3	0,023
<u>Sportive Category %</u>				
Athletics	43,1	46,5	50,0	
Swimming	17,6	14,0	8,3	ns
Basketball	3,9	44,7	0,0	
Others	35,3	34,9	41,7	
<u>Volume of Training, %</u>				
High >5 h/w	41,2	31,0	75,0	0,024
Low< 5 h/w	58,8	69,0	25,0	
Smoker, %	23,5	31,0	25,0	ns
High blood pressure, %	2,0	7,1	0,0	0,048
Dyslipidemia, %	21,6	16,7	0,0	ns
Diabetes, %	0,0	0,0	0,0	ns
<u>CV events %</u>				
Myocardial infarction	0,0	0,0	0,0	ns
Stroke	0,0	0,0	0,0	ns
NSVTM	3,9	4,7	0,0	ns
Time on High-level competition, y	13,8±5,9	11,9±5,8	14,8±5,5	ns
Leaving high-level, y	13,4±6,3	12,8±6,8	12,1±7,0	ns
Study Follow-up, y	22,6±6,2	20,9±6,2	21,3±6,3	ns
ERP location, %				
Inferior	2	-	0,0	
Lateral	49	-	51,3	<0,01
Inferolateral	49	-	48,7	
Any J-point>0.2mV, %	0,0	0,0	8,3	<0.01
QRS pattern, %				
Discrete	38,6	97,1	55,6	
Slurred	19,5	2,9	22,2	<0.01
Notched	31,8	0,0	22,2	
QRS duration, ms	92,9±8,5	90,6±12,1	95,4±12,1	ns
ST-segment deviation, %				
Ascending/upsloping	90,7	66,7	100	ns
Horizontal/descending	9,3	33,3	0,0	
Sokolov-Lyon index>3.5mV, %	21,4	5,7	40,0	0,025

***Abbreviations: ERP = early repolarization pattern; kg = kilograms; BMI = body mass index; m = meters; h = hour; w = week; y = year; mm = millimetres; ms = milliseconds; mV = millivolts; ns = no significance; NSMVT = non-sustained monomorphic ventricular tachycardia.**


Athlete #1
A
B
V4
V5
V6
Athlete #2
A
B
V4
V5
V6
Athlete #3
A
B
II
III
aVF
Athlete #4
A
B
II
III
aVF


1,0
0,8
0,6
0,4
0,2
0,0
Sensitivity
0,0
0,2
0,4
0,6
0,8
1,0
1 - Specificity

- One third of elite athletes presented the benign early repolarization pattern (upsloping ST-segment) whereas the one related to sudden cardiac death risk (rectified/descending ST-segment) was rare.
- Early repolarization pattern persisted in half of athletes after professional sport retirement and no episodes of sudden cardiac death were observed after 24 years of follow-up.