

Original article

Left atrial enlargement in competitive athletes and atrial electrophysiology



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ABSTRACT

Introduction and objectives: There are scarce data on left atrial (LA) enlargement and electrophysiological features in athletes.

Methods: Multicenter observational study in competitive athletes and controls. LA enlargement was defined as LA volume indexed to body surface area ≥ 34 mL/m². We analyzed its relationship with atrial electrocardiography parameters.

Results: We included 356 participants, 308 athletes (mean age: 36.4 ± 11.6 years) and 48 controls (mean age: 49.3 ± 16.1 years). Compared with controls, athletes had a higher mean LA volume index (29.8 ± 8.6 vs 25.6 ± 8.0 mL/m², $P = .006$) and a higher prevalence of LA enlargement (113 [36.7%] vs 5 [10.4%], $P < .001$), but there were no relevant differences in P-wave duration (106.3 ± 12.5 ms vs 108.2 ± 7.7 ms; $P = .31$), the prevalence of interatrial block (40 [13.0%] vs 4 [8.3%]; $P = .36$), or morphology-voltage-P-wave duration score (1.8 ± 0.84 vs 1.5 ± 0.8 ; $P = .71$). Competitive training was independently associated with LA enlargement (OR, 14.7; 95%CI, 4.7–44.0; $P < .001$) but not with P-wave duration (OR, 1.02; 95%CI, 0.99–1.04), IAB (OR, 1.4; 95%CI, 0.7–3.1), or with morphology-voltage-P-wave duration score (OR, 1.4; 95%CI, 0.9–2.2).

Conclusions: LA enlargement is common in adult competitive athletes but is not accompanied by a significant modification in electrocardiographic parameters.

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Dilatación de la aurícula izquierda en deportistas de alta competición y electrofisiología auricular

RESUMEN

Introducción y objetivos: Existe poca información sobre la dilatación de la aurícula izquierda (AI) y los parámetros electrocardiográficos en deportistas.

Métodos: Estudio observacional multicéntrico en deportistas de competición y controles. La dilatación de la AI se definió como un volumen indexado por área de superficie corporal ≥ 34 ml/m². Se estudió su relación con parámetros electrocardiográficos auriculares.

Resultados: Se incluyó en total a 356 sujetos: 308 deportistas de competición (media de edad, $36,4 \pm 11,6$ años) y 48 controles ($49,3 \pm 16,1$ años). Los deportistas de competición tenían un mayor volumen medio indexado de la AI ($29,8 \pm 8,6$ frente a $25,6 \pm 8,0$ ml/m²; $p = 0,006$) y una mayor prevalencia de dilatación de la AI (113 [36,7%] frente a 5 [10,4%]; $p < 0,001$), sin diferencias relevantes en cuanto a la duración de la onda P ($106,3 \pm 12,5$ frente a $108,2 \pm 7,7$ ms; $p = 0,31$), la prevalencia de bloqueo interauricular (40 [13,0%] frente a 4 [8,3%]; $p = 0,36$) ni la puntuación *Morphology-Voltage-P-wave duration* ($1,8 \pm 0,84$ frente a $1,5 \pm 0,8$;

Palabras clave:

Bloqueo interauricular

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Dilatación de la aurícula izquierda

Onda P

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$p = 0,71$). El entrenamiento competitivo se asoció de manera independiente con la dilatación de la AI (OR = 14,7; IC95%, 4,7–44,0; $p < 0,001$), pero no con la duración de la onda P (OR = 1,02; IC95%, 0,99–1,04), el bloqueo interauricular (OR = 1,4; IC95%, 0,7–3,1) o la puntuación *Morphology-Voltage-P-wave duration* (OR = 1,4; IC95%, 0,9–2,2).

Conclusiones: La dilatación de la AI es frecuente en deportistas de competición, pero no se acompaña de una modificación relevante en los parámetros electrocardiográficos.

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Abbreviations

ECG: electrocardiography

IAB: interatrial block

LA: left atrium

LAVi: left atrial volume indexed to body surface area

MVP: morphology-voltage-P-wave duration

INTRODUCTION

Physical exercise is beneficial, but if intensive, it can cause potentially deleterious cardiac remodeling.¹ The characteristics that define “athlete’s heart”^{2,3} include dilatation of the chambers of the heart.⁴ Dilatation of the left atrium (LA) in competitive athletes can be considered an adaptive mechanism, which is not secondary to an increase in left ventricular filling pressures or mitral valve disease.⁵ However, there is a clear association between LA dilatation and an increased rate of cardiovascular events, even in individuals with no supraventricular tachyarrhythmias or valve disease.^{6,7} Recent studies have analyzed the risks associated with LA dilatation in athletes, principally due to the potential predisposition to atrial fibrillation.⁸

Echocardiography is the most frequently used method for assessing LA volume,⁹ and the LA volume indexed to the body surface area (LAVi) has been shown to have prognostic value.¹⁰ Previous studies have indicated a poor correlation between electrocardiographic P wave criteria and LA size in the general population.¹¹ The association between LA dilatation and atrial physiology characteristics has not been analyzed in competitive athletes, a group in which the upper limit for normal LA size is unclear.^{4,5} Our objective was to analyze LA dilatation, P-wave duration, and interatrial block (IAB) in competitive athletes.

METHODS

ALMUDAINA (In Spanish, *Análisis y Lectura de Mediciones Uniformes de Dilatación Auricular Izquierda Notificadas en Atletas*; in English, Analysis and Reading of Uniform Measurements of Left Atrial Dilatation Reported in Athletes) is a national retrospective observational study with 9 participating Spanish hospitals. The study period was from January to September 2020. Individuals who met the study participation criteria were those aged ≥ 16 years, who had a digitalized electrocardiogram (ECG) and a transthoracic echocardiogram done on the same day. The exclusion criteria were the following: a) ischemic heart disease, moderate or severe valve disease, left ventricular ejection fraction

$< 50\%$ or known primary cardiomyopathy (hypertrophic, dilated, arrhythmogenic, or noncompaction); b) significant arrhythmias; c) implanted cardiac device; d) no measurable P waves on surface ECG; e) poor transthoracic window; f) chest-wall abnormality or deformity; and g) chronic obstructive pulmonary disease.

Patients were selected if they met the consensus definition of competitive athlete (participation in an individual or team sport that involves regular competition against other athletes, places great importance on excellence and success, and demands regular and generally intensive training)^{12,13} in a skilled, strength, resistance, or mixed activity, at a national or international level.

The selected controls were individuals not participating in competitive sports (recreational sport was allowed) and not taking part in regular training programs.

A resting 12-lead surface ECG was obtained for each participant in line with established standards (25 mm/s and 10 mm/50 mV), with amplitude filtering of 0.05–150 Hz and a 50-Hz filter. The following P-wave parameters were analyzed: a) duration, b) voltage in lead I, and c) MVP (morphology-voltage-P-wave duration) score.¹⁴ We analyzed the presence of IAB, whether partial (defined as a P wave duration ≥ 120 ms, with positive polarity in the inferior leads) or advanced (P wave duration ≥ 120 ms with a biphasic morphology [\pm] in the inferior leads).¹⁵ The MVP score is a risk scale that can help predict *de novo* atrial fibrillation and is calculated by assigning points according to P-wave morphology in the inferior leads (0–2), its voltage in lead I (0–2), and its duration (0–2).¹⁴ The P-wave duration is measured manually in a central laboratory using GeoGebra 4.2 software after amplifying the original size of the ECG by a factor of 20. All measurements were performed by an observer who was blinded to the patients’ clinical and electrocardiographic data and, if there was any uncertainty, a second observer was consulted.

Two-dimensional transthoracic Doppler echocardiograms were analyzed by experienced echocardiogram specialists and acquired in line with the guidelines of the American Society of Echocardiography/European Association of Cardiovascular Imaging for cardiac chamber quantification.⁹ LA size was quantified at end-systole with the following measurements averaged after 3 consecutive cycles: a) anteroposterior LA diameter (parasternal long-axis view), b) LA area (apical 4-chamber view), and c) LA volume (on apical 2-chamber and 4-chamber views, using the modified biplane method of disc summation). The LA volume was indexed to body surface area to obtain the LAVi. An LAVi ≥ 34 mL/m² was used to define LA dilatation.^{9,16} If the LAVi could not be calculated, LA area (≥ 20 cm²) was used as the criterion to define LA dilatation.⁹ Right atrial dilatation was defined using area (> 18 cm²) or indexed volume (25 mL/m²).

Baseline clinical characteristics were recorded for all participants: age weight, height, cardiovascular risk factors, comorbidities, family history of sudden cardiac death, and pharmacological treatment. Blood pressure was measured with automated devices after a 5-minute rest period.

The study complied with the Declaration of Helsinki and was approved by the local ethics committee of the coordinating hospital. Being a strictly observational, descriptive, retrospective

study, with no participants subject to an intervention, the ethics committee exempted the requirement for an informed consent form.

Statistical analysis

Categorical variables are reported as frequency and percentage. Continuous variables are reported as mean \pm standard deviation or median [interquartile range] if they did not follow a normal distribution. The chi-square test was used for the comparison of categorical variables and Student *t* test, Kruskal-Wallis, or analysis of variance (ANOVA) for comparison of continuous variables. Multivariate logistic regression was used to analyze the association between competitive training and the presence of LA dilatation and the atrial electrocardiographic indices. All the variables were initially included in the model and then selected using backward stepwise regression. To study the association of LA dilatation with participation in competitive sport, we also performed propensity score adjustment. For this, numerical variables and missing values were recoded to avoid losing sample size. The logistic model for case-control prediction showed good calibration (Hosmer-Lemeshow, $P = .549$) and discrimination (receiver operating characteristics [ROC] area under the curve, 0.891). All statistical tests were based on a 2-tailed hypothesis test. Statistical analysis was performed with the software package SPSS, version 23.0 (IBM, USA).

RESULTS

The final population included 356 Caucasian participants: 308 cases and 48 controls. Table 1 summarizes the participants' baseline characteristics. Compared with controls, the athlete group was younger (36.4 ± 11.6 vs 49.3 ± 16.1 years) and had a lower prevalence of cardiovascular risk factors, lower systolic and diastolic blood pressure, and lower heart rate. In the competitive athlete group, the most common type of activity was resistance sports ($n = 221$, 71.8%), followed by strength ($n = 35$ [11.4%]) and a combination of both ($n = 52$ [16.9%]).

Table 2 summarizes the echocardiographic characteristics of the two groups. Compared with controls, the athletes had a higher LAVi (29.8 ± 8.6 vs 25.6 ± 8.0 mL/m²) and higher prevalence of LA dilatation (36.7% vs 10.4%). Interventricular septum thickness, left ventricular volumes, and tricuspid annular plane systolic excursion were also higher in athletes than controls.

Table 3 shows data on ECG evaluation. There were no significant differences between athletes and controls in the electrocardiographic indices: P-wave duration (106.3 ± 12.5 vs 108.2 ± 7.7 ms), IAB prevalence (40 [13.0%] vs 4 [8.3%]) and MVP score (1.8 ± 0.84 vs 1.5 ± 0.8). Only 1 case of advanced IAB was detected in an athlete, who was 37 years old, had no comorbidities, trained for 16 hours per week, and did not have LA dilatation.

Table 4 shows the comparison of participants with and without LA dilatation. Those with LA dilatation had higher mean age, P-wave duration, IAB frequency, and MVP score (1.9 ± 1.0 vs 1.7 ± 0.7 ; $P = .01$). As only 5 controls had LA dilatation, the differences in the electrocardiographic parameters of atrial activation were mainly due to the athletes (table 5).

There was no significant correlation between P-wave duration and LAVi, either in the whole sample (linear correlation coefficient $r = 0.01$; $P = .901$) or in the athlete group ($r = 0.004$; $P = .966$).

Table 6 shows the multivariate analysis for predictors of LA dilatation. Competitive training was independently associated with LA dilatation (odds ratio [OR], 14.7; 95% confidence interval [95%CI], 4.7-44.0). We also forced inclusion in the model of cardiovascular risk factors, ventricular diameters, PR interval duration, and P-wave duration, which produced no significant changes in the association between participation in competitive sports and LA dilatation.

However, competitive training was not associated with P-wave duration (OR, 1.02; 95%CI, 0.99-1.04; $P = .19$), MVP score (OR, 1.4; 95%CI, 0.9-2.2; $P = .14$), or the presence of IAB (OR, 1.4; 95%CI, 0.7-3.1; $P = .34$). The only variables that were independently associated with IAB were age in years (OR, 1.05; 95%CI, 1.01-1.09; $P = .015$) and left ventricular mass in grams (OR, 1.013; 95%CI, 1.004-1.023; $P = .06$).

Table 7 shows the main differences in the clinical, echocardiographic, and electrocardiographic characteristics of the athletes according to the presence of IAB and LA dilatation. Compared with

Table 1
Baseline clinical characteristics of athletes and controls

	Athletes (n = 308)	Controls (n = 48)	P
Age, y	36.4 \pm 11.6	49.3 \pm 16.1	< .001
Female sex	80 (26.0)	20 (41.7)	.024
Weight, kg	74.6 \pm 13.9	77.0 \pm 14.2	.273
Height, cm	175.6 \pm 7.8	170.9 \pm 10.9	< .001
Body mass index, kg/m ²	21.2 \pm 3.4	22.5 \pm 3.5	.017
Body surface area, m ²	1.9 \pm 0.2	1.9 \pm 0.2	.700
Dyslipidemia	13 (4.2)	15 (31.3)	< .001
Smoking			< .001
Active	2 (0.6)	8 (5.0)	
Past	7 (2.3)	5 (10.4)	
Never	226 (73.4)	24 (50.0)	
Diabetes	0	4 (8.3)	< .001
Hypertension	8 (2.6)	12 (25.0)	< .001
Systolic blood pressure, mmHg	125.2 \pm 12.2	130.4 \pm 15.3	.019
Diastolic blood pressure, mmHg	71.0 \pm 9.3	80.5 \pm 10.3	< .001
Heart rate, bpm	66.3 \pm 13.1	74.8 \pm 13.5	< .001

Values are expressed as No. (%) or mean \pm standard deviation.

Table 2
Echocardiographic data from athletes and controls

	Athletes (n = 308)	Controls (n = 48)	P
Left atrium			
Anteroposterior diameter, mm	36.0 ± 4.6	34.6 ± 2.6	.378
Volume, mL	54.2 ± 18.9	36.2 ± 15.2	.015
LAVi, mL/m ²	29.8 ± 8.6	25.6 ± 8.0	.006
LA dilatation	113 (36.7)	5 (10.4)	< .001
Mild	98 (31.8)	5 (10.4)	
Moderate	10 (3.2)	0	
Severe	5 (1.6)	0	
Left ventricle			
IVS, mm	9.7 ± 1.55	8.8 ± 1.6	.002
PW, mm	9.6 ± 2.7	9.1 ± 6.2	.526
EDD, mm	51.6 ± 4.3	48.0 ± 5.7	< .001
ESD, mm	32.1 ± 4.2	27.4 ± 5.5	< .001
Mass, g	183.4 ± 48.6	175.8 ± 31.1	.685
Indexed mass, g/m ²	96.0 ± 22.1	88.0 ± 11.3	< .001
LVEF, %	68.1 ± 5.1	72.9 ± 5.4	< .001
E wave, cm/s	90.9 ± 21.0	80.3 ± 16.2	.188
A wave, cm/s	59.1 ± 19.3	54.1 ± 11.9	.492
E/A ratio	1.6 ± 0.5	1.3 ± 1.0	.707
DT, ms	200.8 ± 38.6	201.4 ± 41.4	.965
E/e' ratio	5.7 ± 1.5	7.5 ± 1.8	< .001
Transmitral filling pattern			.483
Normal	273 (88.6)	44 (91.7)	
Impaired relaxation	34 (11.0)	4 (8.3)	
Pseudonormal	1 (0.3)	0	
Restrictive	0	0	
Right heart			
TAPSE, mm	25.9 ± 2.7	23.2 ± 3.8	< .001
Right atrial dilatation	119 (38.6)	6 (12.5)	.002
Aorta			
Ascending, mm	29.43 ± 5.28	31.57 ± 4.48	.060
Aortic arch, mm	23.01 ± 3.56	25.57 ± 3.21	.075

DT, deceleration time; EDD, end-diastolic diameter; ESD, end-systolic diameter; IVS, interventricular septum; LA, left atrium; LAVi, left atrial volume indexed to body surface area; LVEF, left ventricular ejection fraction; PW, posterior wall; TAPSE, tricuspid annular plane systolic excursion. Values are expressed as No. (%) or mean ± standard deviation.

Table 3
ECG data from athletes and controls

	Athletes (n = 308)	Controls (n = 48)	P
P wave			
Duration, ms	106.3 ± 12.5	108.2 ± 7.7	.313
Voltage in lead I, mV	0.08 ± 0.04	0.08 ± 0.04	.791
Interatrial block	40 (13.0)	4 (8.3)	.359
MVP score	1.8 ± 0.8	1.5 ± 0.8	.071
Other ECG data			
PR interval, ms	167.0 ± 25.1	164.8 ± 21.5	.558
Right bundle branch block			.046
No	259 (84.1)	46 (95.8)	
Incomplete	45 (14.6)	1 (2.1)	
Complete	3 (1.0)	1 (2.1)	
QRS width/duration, ms	84.3 ± 11.2	84.8 ± 10.9	.794
QRS axis, °	55.2 ± 30.1	49.7 ± 28.4	.234
Corrected QT interval, ms	392.8 ± 23.3	398.2 ± 26.2	.143

ECG, electrocardiogram; MVP, morphology-voltage-P-wave duration. Values are expressed as No. (%) or mean ± standard deviation.

Table 4

Clinical, echocardiographic, and electrocardiographic data from participants with and without left atrial dilatation

	Dilated LA (n=118)	Undilated LA (n=238)	P
Age, y	40.73 ± 12.5	36.8 ± 13.1	.008
Athlete	113 (95.8)	195 (81.9)	.001
Male sex	78 (66.1)	178 (74.8)	.086
Type of training			.111
Resistance	18 (15.3)	17 (7.1)	
Strength	20 (16.9)	32 (13.4)	
Body mass index	22.6 ± 3.5	20.8 ± 3.3	.001
Body surface area, m ²	1.97 ± 0.2	1.86 ± 0.2	.001
Hours of sport per week	10.0 ± 5.1	10.6 ± 4.6	.519
Hypertension	5 (4.2)	15 (6.3)	.334
Type 2 diabetes mellitus	1 (0.8)	3 (1.3)	.675
Smoking	5 (4.2)	17 (7.1)	.215
Dyslipidemia	6 (5.1)	22 (9.2)	.120
LAVi, mL/m ²	41.3 ± 5.2	25.1 ± 5.8	.001
Right atrial dilatation	57 (48.3)	68 (28.6)	.551
Left ventricular hypertrophy	49 (41.4)	38 (16.0)	.001
LVEDD, mm	52.6 ± 4.1	49.9 ± 5.1	.001
Transmitral filling pattern			.367
Normal	102 (86.4)	215 (90.3)	
Impaired relaxation	16 (13.6)	22 (9.2)	
Pseudonormal or restrictive	0	1 (0.4)	
E/e'	6.0 ± 1.6	6.1 ± 1.8	.580
P wave duration, ms	110.2 ± 13.9	104.7 ± 10.5	< .001
P wave voltage in lead I, mV	0.08 ± 0.04	0.08 ± 0.05	.916
PR interval, ms	172.4 ± 27.6	163.89 ± 22.5	.002
QRS width/duration, ms	84.9 ± 11.7	84.15 ± 10.9	.546
QTc interval, ms	394.8 ± 25.9	392.9 ± 22.7	.479
Right bundle branch block			.434
No	104 (88.1)	201 (84.5)	
Incomplete	12 (10.2)	34 (14.3)	
Complete	2 (1.7)	2 (0.8)	
Interatrial block			.001
No	94 (79.7)	217 (91.2)	
Partial	24 (20.3)	19 (8.0)	
Advanced	0	1 (0.4)	
MVP score	1.9 ± 1	1.67 ± 0.7	.026

LA, left atrium; LAVi, left atrial volume indexed to body surface area; LVEDD, left ventricular end-diastolic diameter; MVP, morphology-voltage-P-wave duration. Values are expressed as No. (%) or mean ± standard deviation.

Table 5

P wave values in athletes and controls with and without left atrial dilatation

Athletes (n=308)	LA dilatation (n=113)	No LA dilatation (n=195)	P
P wave duration, ms	110.3 ± 14.1	103.9 ± 10.9	< .001
Interatrial block	23 (20.4)	17 (8.8)	.004
MVP score	1.9 ± 1.0	1.7 ± 0.7	.081
Controls (n=48)	LA dilatation (n=5)	No LA dilatation (n=43)	
P wave duration, ms	108.4 ± 7.4	108.1 ± 7.8	.939
Interatrial block	1 (20.0)	3 (7.0)	.366
MVP score	2.0 ± 1.2	1.5 ± 0.4	.177

LA, left atrium; MVP, morphology-voltage-P-wave duration. Values are expressed as No. (%) or mean ± standard deviation.

Table 6

Multivariate analysis with independent predictors of left atrial dilatation

	OR (95%CI)	P
Athlete	14.7 (4.7–44.0)	< .001
Age	1.04 (1.008–1.072)	.014
Male	0.23 (0.09–0.61)	.003
Body surface area	43.1 (2.9–633.3)	.006
Left ventricular mass	1.02 (1.01–1.03)	< .001
Heart rate	0.966 (0.939–0.995)	.019

95%CI, 95% confidence interval; OR, odds ratio.

the other 3 groups, athletes with IAB and LA dilatation were older and more frequently female, and had a greater left ventricular mass.

Table 8 shows the association of LA dilatation with competitive sport using propensity score adjustment.

DISCUSSION

Our study shows that, despite being younger and healthier than controls, athletes had a far higher prevalence of LA dilatation, although this finding correlated poorly with electrocardiographic changes.

Left atrial dilatation and remodeling in athletes are practically defining characteristics of athlete's heart.^{3,4} However, the threshold for defining normal LA size in athletes is a matter of debate.^{5,17} Two meta-analyses have demonstrated that LA volume is significantly larger in athletes than in controls. However, the studies analyzed yielded heterogeneous results on the prevalence of LA dilatation, presumably due to differences in the sporting discipline (strength or resistance training), level of training, and age.^{18,19} Rates of LA dilatation of up to 42% to 8% have been described in elite rowers²⁰ and professional basketball players,^{21,22} although severe dilatation is an uncommon finding. Our data confirm both the association between competitive sport and LA dilatation and that severe LA dilatation is rare (only 1.6% of our athletes).

The main contribution of the ALMUDAINA study is that it demonstrates that competitive training in athletes is not associated with longer P-wave duration or presence of IAB. Despite a high prevalence of LA dilatation, we found no significant changes in the atrial electrocardiographic parameters. A recent study in young athletes showed that less than 1% had a P-wave duration ≥ 120 ms and a negative component ≥ 1 mm deep in lead V1.²³ Even in the general population, the electrocardiographic

Table 8

Association between left atrial dilatation and participation in competitive sport using propensity score adjustment

	OR (95%CI)	P
PS adjusted	9.19 (2.70–31.32)	< .001
PS stratified	6.49 (2.19–19.26)	.001
PS matched	10.54 (2.00–55.47)	.005
Inverse probability weighting	13.91 (3.23–59.97)	< .001

95%CI, 95% confidence interval; OR, odds ratio; PS, propensity score.

criteria for LA dilatation have shown low sensitivity.^{11,24,25} Furthermore, changes in P-wave duration and morphology may be due to an IAB in normal-sized atria. This has been demonstrated experimentally²⁶ and in situations such as the presence of an atrial tumor, which can cause IAB without LA dilatation.²⁷ Our study also supports the argument that LA dilatation and IAB are 2 different entities, as most of our athletes with LA dilatation did not have IAB.

However, the consensus documents of the American Heart Association regarding athletes recommend that any change in the P-wave, whether due to LA dilatation or IAB, should be considered a “P-wave abnormality”^{28,29}; we think that this may actually increase confusion regarding LA assessment. Furthermore, the ECG index with the highest diagnostic sensitivity for LA dilatation (Morris index) has a low reproducibility,³⁰ and P wave negativity increases when lead V1 is positioned in the second intercostal space.³¹ In addition, this pattern in V1 could simply represent an interatrial conduction defect.²⁵

Nonetheless, compared with athletes without LA dilatation, those with LA dilatation had a longer P-wave duration (110 vs 104 ms) and a higher prevalence of IAB (20% vs 9%). Therefore, we could hypothesize that it is likely that there is also a certain degree of electrical remodeling in athletes with LA dilatation. However, the fact that none of the athletes with LA dilatation had advanced IAB also indicates a less pathological LA dilatation in association with sports training.

The 2017 international recommendations for ECG interpretation in athletes emphasized that LA dilatation on ECG remains a borderline variant not requiring further cardiological assessment, unless accompanied by other abnormalities.²⁹ This recommendation is supported by the findings of our study (competitive training was not associated with P-wave ECG indices).

Regarding the association of other variables with LA dilatation, our data are in agreement with previous studies reporting an association between age^{32,33} and female sex and LA dilatation.^{32,34}

Table 7

Main differences in clinical, echocardiographic, and electrocardiographic characteristics in athletes, according to presence of interatrial block and left atrial dilatation

	No IAB or LA dilatation (n = 178)	IAB without LA dilatation (n = 17)	LA dilatation without IAB (n = 90)	IAB and LA dilatation (n = 23)	P*
Age, y	34.3 \pm 11.2	34.6 \pm 7.7	38.8 \pm 11.6	43.7 \pm 12.8	< .001
Male sex	139 (78.1)	14 (82.4)	64 (71.1)	11 (47.8)	.013
Body Surface area, m ²	1.9 \pm 0.2	1.9 \pm 0.3	1.9 \pm 0.2	2.0 \pm 0.2	.024
Left ventricular mass, g	169.6 \pm 44.6	186.5 \pm 61.5	200.8 \pm 45.0	219.5 \pm 44.4	< .001
LAVi, mL/m ²	25.6 \pm 5.3	28.3 \pm 5.9	41.7 \pm 5.8	37.0 \pm 0.1	< .001
Heart rate, bpm	68.9 \pm 13.3	65.8 \pm 8.3	62.3 \pm 12.6	62.3 \pm 12.7	.004
P wave duration, ms	102.1 \pm 9.3	122.7 \pm 9.0	105.6 \pm 11.1	128.8 \pm 8.1	< .001

IAB, interatrial block; LA, left atrium; LAVi, left atrial volume indexed to body surface area.

* For the comparison of the 4 groups.

Limitations

Certain limitations of this study must be recognized. Left atrial volume index was calculated with 2-dimensional echocardiography and not cardiac magnetic resonance. Women were under-represented in the athlete group, and as the athletes' hearts may have differential adaptations to exercise,^{23,35} our results are mainly extrapolable to the male subgroup. Our sample is heterogeneous, as it was not limited to a single sport and included athletes with different training levels and intensity. Although this could be viewed as a limitation, it also contributes to the generalizability of our findings. We did not analyze the correlation between LA function and stiffness (measured by strain).^{36–39} The mean age of the adult athletes in our study (36 years) may be considered relatively old. This may partly be because 89% did resistance sports (combined with strength in 17%). However, some previous studies in athletes in Spain were also performed in populations of relatively advanced age: 29,⁴⁰ 40,⁴¹ and 52⁴² years. The small number of controls (explained by the COVID-19 pandemic) is also a limitation, although in the different adjustment options with propensity scoring a clear association was maintained between LA dilatation and competitive sports. We do not believe that the characteristics of the controls recruited was influenced by the pandemic but rather by their low number. Of note, the prevalence of LA dilatation found in our control group (10%) was higher than previously reported in the general population of 35 years and older (6%),⁴³ so the difference in LA dilatation prevalence between our group of athletes (37%) and the general population may be even greater. To date, this is the first study to assess the association between LA dilatation and P-wave electrocardiographic indices in athletes.

CONCLUSIONS

Left atrial dilatation is common in athletes, but is not accompanied by significant changes in electrocardiographic parameters. Our data support the hypothesis that LA dilatation and IAB are 2 different entities. These findings may not be extrapolable to younger athletes, in whom prospective targeted studies of LA dilatation and electrocardiographic parameters should be performed.

WHAT IS KNOWN ABOUT THE TOPIC?

- The association between LA dilatation and atrial electrophysiological characteristics has not been analyzed in athletes, a group without an established definition of the upper limit of normality for LA size.

WHAT DOES THIS STUDY ADD?

- ALMUDAINA is a multicenter study that evaluates the correlation between LA dilatation (based on anatomic criteria) and electrocardiographic parameters of atrial enlargement. Although LA dilatation is common in athletes, it is not accompanied by longer P-wave duration, higher prevalence of IAB, or higher MVP score (a predictor of risk of atrial fibrillation). Our data show that sport is associated with an atrial remodeling that has little expression on surface ECG and suggests that LA dilatation and IAB are different entities.

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AUTHORS' CONTRIBUTIONS

Definition of study objectives and design (M. Martínez-Sellés, C. Herrera), data collection (all authors), data analysis, interpretation of results, and writing first draft of article (M. Martínez-Sellés, C. Herrera). All authors have reviewed and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The authors have no conflicts of interest. The authors would like to thank José María Bellón Cano, research statistician at the Instituto de Investigación Sanitaria Gregorio Marañón for performing the propensity score adjustment.

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