

## Gender-Related Electrocardiographic Changes in Athletes

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**ABSTRACT:** Objectives: To assess gender differences in training-related electrocardiographic (ECG) patterns of athletes, highlighting the importance of these differences for ECG interpretation used in the cardiovascular screening of athletes. Design: Observational cross-sectional study. Methods: 315 athletes were enrolled in the study (150 males and 165 females, mean age 23,7±6,6 and 20,7±6,8, respectively). All study participants underwent clinical examination and 12-lead electrocardiogram (12-lead ECG), scored according to 2017 International recommendations for electrocardiographic interpretation in athletes. Results: Males were older (23,7±6,6 years vs. 20,7 years±6,8;  $p<0,0001$ ) and had more years of training (11,8±6,7 vs. 9,07±6,1;  $p=0,0003$ ) than female athletes. Female athletes had significantly higher resting heart rates (67/min vs. 61/min;  $p<0,0001$ ) and QTc intervals (424,5±19,4ms vs. 338,6±22,3ms;  $p<0,0001$ ). Male athletes were more likely to have isolated QRS voltage criteria for left ventricular hypertrophy (Sokolow-Lyon index) (2,6±0,8mV vs. 2,05±0,5mV;  $p<0,0001$ ) and QRS duration (96,1±13,1ms vs. 86,9±9,4ms;  $p<0,0001$ ). Sinus bradycardia <50bpm was more commonly seen in male athletes than in female (14% vs. 5,45%;  $p=0,009$ ). Sinus arrhythmia occurred more frequently in female athletes (21,8% vs. 12,6%;  $p=0,03$ ). Conclusions: This study demonstrates gender-related differences in ECGs of trained athletes that should be considered in their cardiovascular screening.

**KEYWORDS:** athlete's heart, electrocardiogram, gender

### Introduction

Electrocardiographic changes in athletes are common, comprising all the structural, physiological and electrical remodeling of the heart induced by regular and sustained physical exercise [1]. It is well established that cardiovascular preparticipation assessments results are influenced by type, intensity and duration of training and may change over time [2]. Over the years, in an effort to distinguish normal athlete ECGs from pathological ones, standardized criteria have been introduced. Starting 2005, when Corrado et al. [3] introduced the Lausanne ECG criteria for athlete's ECG interpretation, a number of recommendations have been proposed in order to improve sensitivity and specificity: the 2010 European Society of Cardiology (ESC) updated version [4], the Seattle Criteria introduced by Drezner et al. in 2013 [5], finally the 2017 International recommendations for electrocardiographic interpretation in athletes [6].

Factors such as age, gender, ethnicity, type of sport, intensity of training, neurohumoral and environmental influences are mentioned when describing cardiac remodeling in athletes. Based on the mechanical action of the muscles involved, Mitchell et al. [2] divided exercise into

two types: dynamic and static, both producing an increase in cardiac mass. This finding has been debated in numerous electrocardiographic and echocardiographic studies [7-9].

It is well known that gender influences both structural and electrical cardiac remodeling in athletes, regardless the age and type of training. But the international recommendations for ECG interpretation use the same normal range values for male and for female athletes, except for the long QT criteria, which is gender-related [10]. The effects of sports on ECG parameters have been debated in numerous studies, but most are related to male athletes, while few data are available regarding the effect of long-term exercise training on the woman's heart [11].

The present study aims to evaluate electrocardiographic gender-related differences in highly trained young athletes, while highlighting the implications of these differences in their cardiovascular screening.

### Material and methods

This observational study was conducted at the Sports Medical Center of Craiova, from September 2017 to January 2018. We enrolled 315 athletes (150 males and 165 females), engaged in a variety of sporting discipline (runners, soccer players, martial arts, basketball, volleyball), whom underwent routine

cardiovascular screening. Mean age was 23,7±6,6 years for males and 20,7±6,8 years for females.

Assessment of all study participants included personal and family history, clinical examination with anthropometric data (height, body weight, body surface area) and 12-lead electrocardiogram.

The study was performed according to the tenets of the Declaration of Helsinki and the University Ethics Committee approved the research protocol. Informed consent was obtained from all subjects prior to the study.

**Electrocardiographic assessment.** Standard 12-lead ECG was acquired at a paper speed of 25mm/s and a scale of 10mm/mV, using a General Electric MAC5500 machine. The tracings were analyzed by an experienced observer, who was blind to the characteristics of the patients. The assessment comprised the heart rhythm and rate (HR; bpm), PR interval, QRS duration, amplitude and axis, STJ amplitude, T wave morphology, QT interval, corrected QT interval calculated according to the Bazett's formula.

All ECG tracings were assessed for the presence of supraventricular, junctional or ventricular arrhythmias. Sinus bradycardia in athletes was defined as a resting HR <50bpm, sinus arrhythmia as heart rate variation with respiration, first-degree atrioventricular block as prolonged PR interval >200ms; incomplete right bundle branch block (iRBBB) as an rSR' pattern in lead V1 and a qRS pattern in lead V6 with QRS duration <120ms. For isolated QRS voltage criteria of left ventricular

hypertrophy (LVH), we used the Sokolow-Lyon index (V1+R V5 or V6 >3.5mV). The ECG tracings were also evaluated for the presence of early repolarization (ER), which was defined as J point (offset of QRS complex) elevation, ST elevation, J waves, or terminal QRS slurring in the inferior and/or lateral leads (6). The variant for black athlete's repolarization consists in a J-point elevation with a convex ST segment elevation, followed by T wave inversion in V1-V4 leads. Regarding the athletes aged under 16, T-wave inversion in V1-V3 was considered normal finding. All ECG tracings were also assessed for the presence of ventricular pre-excitation. According to guidelines, short-PR interval without delta wave has been reported as a normal variant of an athlete's ECG.

**Statistical analysis** was performed using XLSTAT 2014 for MS Excel (Addinsoft SARL, Paris, France). Results are reported as mean±standard deviation (SD). The Student-t test was used to compare the continuous variables, when the normality hypothesis was met; if not, non-parametric tests (Mann-Whitney or Kruskal-Wallis) were performed. The categorical variables were analyzed using Chi-square test or Fisher's F test, as appropriate. A p <0.05 value was considered statistically significant for the comparison of several groups.

**Results**

In this study, we included 315 athletes: 150 males and 165 females. Most of the subjects were involved in basketball, followed by volleyball and athletics (Fig.1).

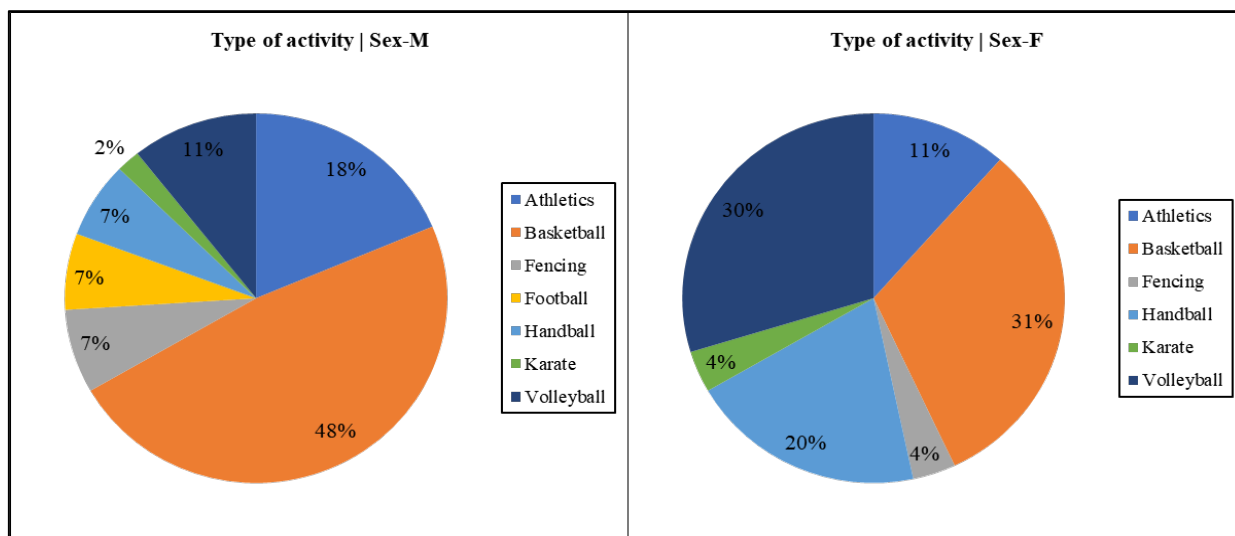


Fig.1. Relative frequency of sport type, by sex groups

Male athletes were older (23,7±6,6 years vs. 20,7 years±6,8; p<0,0001) and had more years of training (11,8±6,7 years vs. 9,07±6,1 years; p=0,0003) than female athletes. The subjects had negative family history of sudden cardiac death.

The anthropometric data such as height, weight and body surface area were significantly higher in male athletes than in females. Mean values and standard deviations for all population characteristics are presented in Table 1.

**Table 1. Demographic characteristics by gender groups. BSA (body surface area, m<sup>2</sup>); VO<sub>2</sub> max (maximum rate of oxygen consumption measured during incremental exercise)**

Variable	Male				Female				p
	Mean	Std. dev.	Min	Max	Mean	Std. dev.	Min	Max	
Age (years)	23,7	6,6	13	41	20,7	6,8	11	43,0	<0,0001
Height (cm)	184,5	13,9	149,0	225,0	169,0	9,6	144,5	192,5	<0,0001
Weight (kg)	81,0	17,8	44,0	140,0	60,3	12,4	31,0	99,0	<0,0001
BSA (m <sup>2</sup> )	2,02	0,29	1,35	2,93	1,66	0,21	1,10	2,26	<0,0001
Years of training	11,8	6,7	1	30	9,07	6,19	1	32	0,0003
VO2 max	0,70	0,11	0,49	0,93	0,66	0,11	0,42	0,95	0,0108

Training-related ECG changes as significantly greater isolated QRS voltage criteria for left ventricular hypertrophy (LVH) (2,6±0,8 vs. 2,05±0,5; p<0,0001) and QRS duration (96,1±13,1ms vs. 86,9±9,4ms; p<0,0001) were seen in male athletes. More frequent sinus bradycardia <50bpm was also

seen in male athletes (14% vs. 5,45%; p=0,009), while female athletes had significantly higher resting heart rates (67/min vs. 61/min; p<0,0001) and higher QTc duration (424,5±19,4ms vs. 338,6±22,3 ms; p<0,0001). Electrocardiographic changes are illustrated in Table 2

**Table 2. Mean values and standard deviations in electrocardiographic parameters by gender groups**

Variable	Male				Female				p
	Mean	Std. dev.	Min	Max	Mean	Std. dev.	Min	Max	
Heart rate (bpm)	61,7	12,9	35	102	67,6	12,6	40	105	<0,0001
PR interval (ms)	146,9	32,4	80	220	139,8	28,6	75	220	ns
QRS axis (°)	61,0	30,2	-45	100	69,0	16,9	10	110	ns
QRS duration (ms)	96,1	13,1	70	130	86,9	9,4	70	130	<0,0001
RV5+SV1 (mV)	2,64	0,82	1	5	2,05	0,59	0,8	3,9	<0,0001
QT (ms)	390,6	40,8	310	508	384,0	36,2	300	480	ns
QTc (ms)	338,6	22,3	303,5	398,5	424,5	19,4	399,5	490,7	<0,0001

As shown in Table 3, sinus arrhythmia occurred more frequently in female athletes (21,8% vs. 12,6%; p=0,03). We found no significant gender-related differences in PR interval duration, QRS axis, incomplete or complete RBBB and first-degree atrioventricular blocks or early repolarization pattern.

**Table 3. Rhythm and conduction disorders by sex groups. AV (atrioventricular); RBBB (right bundle branch block)**

	Male	Female	p Chi <sup>2</sup>
Sinus arrhythmia	19 (12,6%)	36 (21,8%)	0,0326
Sinus bradycardia <60bpm	60 (40%)	45 (27,2%)	0,0167
Sinus bradycardia <50bpm	21 (14%)	9 (5,45%)	0,0099
First degree AV block	10 (6,6%)	9 (5,45%)	ns
Incomplete RBBB	14 (9,3%)	9 (5,45%)	ns
Complete RBBB	6 (4%)	4 (2,4%)	ns
Early repolarization	24 (16%)	22 (13,3%)	ns

## Discussion

The athlete's heart is defined by the physiological changes in cardiac morphology and electrophysiology, as a result to regular and sustained training [5]. The electrocardiographic examination (12-lead ECG) is mandatory in cardiovascular screening in athletes, being scored according to the guidelines. Hence, ECG interpretation in athletes can reveal training-related pattern or an underlying pathology. In 2010, the Sports Department of the European Society of Cardiology proposed the division of athletes' ECG changes into two groups: the first group (group 1) comprised the common, training-related ECGs changes and the second group (group 2), the uncommon and training-unrelated changes. The guidelines recommended that an athlete with a change from group 1 does not require further assessment, while an athlete with an ECG change from group 2 should be

proposed to further investigation [4]. Over the last decade, efforts have been made to update the criteria for the interpretation of the athletes' ECGs to improve their specificity, while retaining high accuracy for detection of underlying pathology or of those at risk of sudden cardiac death. Thus, in 2013, a group of experts published the Seattle criteria, which became widely used [5]. In 2014, Sheikh et al. proposed further updates to the interpretation of ECG. A 'borderline group' had been separated, thus recognizing that selected changes from group 2 according to the ESC (i.e. left and right atrium enlargement, left axis deviation, right axis deviation, complete RBBB and right ventricular hypertrophy) would be treated as benign, if presented in isolation [12].

The effects of exercise on ECG parameters have been matter of debate in numerous studies, mainly related to male athletes, while few data are available regarding the effect of long-term exercise training on the woman's heart [5]. It is well known that gender influences both structural and electrical cardiac remodeling in athletes, regardless the age and type of training, but the international recommendation still uses the same normal range values for male and for female athletes, except for the long QT criteria, which is different and gender-related [10].

Mandic et al. [13] assessed the effect of gender on computerized electrocardiogram in 658 college athletes (54% male athletes) and found that larger QRS duration, PR interval, Q wave duration and J point amplitude were seen in male, while women displayed higher QTc intervals, similar finding to our study. As concluded by Mandic, electrocardiographic measurements correlated poorly with anthropometric dimensions such as body surface area.

In 2014, Wasfy et al. [14] summarized gender-related ECG differences in a group of 330 competitive rowers as a reference for other ECG screenings in rowers, but did not debate possible implications for screening in pre-participation assessment. The authors noticed greater amounts of left ventricular hypertrophy and early repolarization in male vs. female athletes.

Recently, in the study led by Bessem et al. [15] on 1436 athletes, of which 72% were male, the results were closer to ours. They found that male athletes had significantly more sinus bradycardia, QRS duration, and isolated QRS voltage criteria for LVH, whereas female athletes had a significantly higher resting heart

rate, findings which were similar with our observations. As opposed to our study, they also found that PR interval, incomplete RBBB and early repolarization is more common in male vs. female athletes, while sinus arrhythmias, and first-degree AV blocks showed no gender-related differences, while we found that sinus arrhythmia is more common in female athletes.

In our country, the lack of guidelines on preparticipation examination is a major matter of debate, 12-lead ECG being the main tool and mandatory for cardiovascular disease screening in athletes. Therefore, in sports medicine, the impact of an abnormal electrocardiogram is outstanding, being merit for further investigation [15].

All these findings prove that gender, beside type of sport, intensity of training and inherited genetic factors, is a strong determinant of the cardiac remodeling in athlete's heart and by using different and gender related cut-off values, efficacy and accuracy of routine ECG interpretation in preparticipation assessment of athletic population may be improved, with fewer false-positive or false-negative screening results.

The limitation of our study consists in the heterogeneity of our study population, regarding the age and type of sports discipline. Another limitation is the lack of a matched non-athletic group by age, sex, height and weight, which would have allowed us to compare the ECG parameters and conclude whether gender differences are related to training.

## Conclusion

The results of our research demonstrate differences in heart rate, sinus bradycardia, sinus arrhythmia, QRS duration and left ventricular hypertrophy index, when comparing ECGs patterns between male athletes versus female athletes. Our study highlights once more the differences between ECG parameters when related to the gender, but further evidence is needed to establish different cut-off values for interpreting ECG parameters in athletes.

## References

1. Drezner JA, Fischbach P, Froelicher V, Marek J, Pelliccia A, Prutkin JM, Schmied CM, Sharma S, Wilson MG, Ackerman MJ, Anderson J, Ashley E, Asplund CA, Baggish AL, Börjesson M, Cannon BC, Corrado D, DiFiori JP, Harmon KG, Heidbuchel H, Owens DS, Paul S, Salerno JC, Stein R, Vetter VL. Normal electrocardiographic findings: recognising physiological adaptations in athletes. *Br J Sports Med*, 2013, 47(3):125-136.

2. Mitchell JH, Haskell W, Snell P, Van Camp SP. Task Force 8: classification of sports. *J Am Coll Cardiol*, 2005, 45(8):1364-7.
3. Corrado D, Pelliccia A, Bjørnstad HH, Vanhees L, Biffi A, Borjesson M, Panhuyzen-Goedkoop N, Deligiannis A, Solberg E, Dugmore D, Mellwig KP, Assanelli D, Delise P, van-Buuren F, Anastasakis A, Heidbuchel H, Hoffmann E, Fagard R, Priori SG, Basso C, Arbustini E, Blomstrom-Lundqvist C, McKenna WJ, Thiene G; Study Group of Sport Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology, and Consensus Statement of the Study Group of Sport Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology. Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol. Consensus statement of the study group of sport cardiology of the working group of cardiac rehabilitation and exercise physiology and the working group of myocardial and pericardial diseases of the european society of cardiology. *Eur Heart J*, 2005, 26 (5):516–524.
4. Corrado D, Pelliccia A, Heidbuchel H, Sharma S, Link M, Basso C, Biffi A, Buja G, Delise P, Gussac I, Anastasakis A, Borjesson M, Bjørnstad HH, Carrè F, Deligiannis A, Dugmore D, Fagard R, Hoogsteen J, Mellwig KP, Panhuyzen-Goedkoop N, Solberg E, Vanhees L, Drezner J, Estes NA 3rd, Iliceto S, Maron BJ, Peidro R, Schwartz PJ, Stein R, Thiene G, Zeppilli P, McKenna WJ, Section of Sports Cardiology, European Association of Cardiovascular Prevention and Rehabilitation. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. *Eur Heart J*, 2010, 31(2):243-259.
5. Drezner JA, Ackerman MJ, Anderson J, Ashley E, Asplund CA, Baggish AL, Börjesson M, Cannon BC, Corrado D, DiFiori JP, Fischbach P, Froelicher V, Harmon KG, Heidbuchel H, Marek J, Owens DS, Paul S, Pelliccia A, Prutkin JM, Salerno JC, Schmied CM, Sharma S, Stein R, Vetter VL, Wilson MG. Electrocardiographic interpretation in athletes: the 'Seattle criteria'. *Br J Sports Med*, 2013, 47(3):122-124.
6. Sharma S, Drezner JA, Baggish A, Papadakis M, Wilson MG, Prutkin JM, La Gerche A, Ackerman MJ, Borjesson M, Salerno JC, Asif IM, Owens DS, Chung EH, Emery MS, Froelicher VF, Heidbuchel H, Adamuz C, Asplund CA, Cohen G, Harmon KG, Marek JC, Molossi S, Niebauer J, Pelto HF, Perez MV, Riding NR, Saarel T, Schmied CM, Shipon DM, Stein R, Vetter VL, Pelliccia A, Corrado D. International recommendations for electrocardiographic interpretation in athletes. *J Am Coll Cardiol*, 2017, 69(8):1057-1075.
7. Asmussen E. Similarities and dissimilarities between static and dynamic exercise. *Circ Res*, 1981, 48(1):13-10.
8. Mitchell JH, Wildenthal K. Static (isometric) exercise and the heart: physiological and clinical considerations. *Annu Rev Med*, 1974, 25:369-381.
9. Gallagher KM, Raven PB, Mitchell JH. Classification of sports and the athlete's heart. In: Williams RA (Ed): *The athlete and heart disease: Diagnosis, evaluation and management*. Lippincott Williams & Wilkins, 1999, Philadelphia, 9-21.
10. Di Paolo FM, Pelliccia A. The "Athlete's Heart": Relation to Gender and Race. *Cardiol Clin*, 2007, 25(3):383-389.
11. Jakubiak AA, Burkhard-Jagodzińska K, Król W, Konopka M, Bursa D, Sitkowski D, Kuch M, Braksator W. The differences in electrocardiogram interpretation in top-level athletes. *Kardiol Pol*, 2017, 75(6):535-544.
12. Sheikh N, Papadakis M, Ghani S, Zaidi A, Gati S, Adami PE, Carré F, Schnell F, Wilson M, Avila P, McKenna W, Sharma S. Comparison of electrocardiographic criteria for the detection of cardiac abnormalities in elite black and white athletes. *Circulation*, 2014, 129(16):1637-1649.
13. Mandic S, Fonda H, Dewey F, Le VV, Stein R, Wheeler M, Ashley EA, Myers J, Froelicher VF. Effect of gender on computerized electrocardiogram measurements in college athletes. *Phys Sportsmed*, 2010, 38(2):156-164.
14. Wasfy MM, DeLuca J, Wang F, Berkstresser B, Ackerman KE, Eisman A, Lewis GD, Hutter AM, Weiner RB, Baggish AL. ECG findings in competitive rowers: normative data and the prevalence of abnormalities using contemporary screening recommendations. *Br J Sports Med*, 2015, 49(3):200-206.
15. Bessem BB, de Bruijn MM, Nieuwland WW. Gender differences in the electrocardiogram screening of athletes. *J Sci Med Sport*, 2017, 20(2):213-217.

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