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Electrocardiographic Changes in Child Athletes

Melis Akpınar Gözetici[1], Aysenur Bostan Kantarcı[2], Yelda Türkmenoğlu[2], Hasan Dursun[2], Ahmet İrdem[3]

[1]Department of Pediatrics, Sancaktepe Şehit Prof. Dr. İlhan Varank Training and Research Hospital, İstanbul, Turkey
[2]Department of Pediatrics, Prof. Dr. Cemil Taşçıoğlu City Hospital, İstanbul, Turkey
[3]Department of Pediatric Cardiology, Prof. Dr. Cemil Taşçıoğlu City Hospital, İstanbul, Turkey

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Abstract

Objective: This study aimed to investigate changes in cardiac function in child athletes.

Methods: Electrocardiogram and echocardiograms of 136 child athletes were included. Heart rate, rhythm, electrical axis, P wave duration, PR interval, QRS interval, sum of V1-S + V5-R wave amplitude, V1-S/V5-R amplitude ratio, sum of V1-S + V6-R wave amplitude, V1-S/V6-R amplitude ratio, QT and QTc intervals, QT and QTc dispersions, JT and JTc intervals T peak-end (Tp-e) interval, presence of early repolarization pattern, left ventricular internal dimension in diastole and systole, and fractional shortening were recorded. The data were compared to the control group of 90.

Results: In the child athletes, the mean QRS amplitude, QT interval, QTd, JT interval, Tp-e, left ventricular internal dimension in diastole and systole were found to be increased and heart rate was found to be decreased compared to the control group. The differences were statistically significant. In children who had exercised more than 1000 hours, mean heart rate was found to be decreased, PR interval, QRS interval, V1-S + V5-R wave amplitude, and left ventricular internal dimension in systole were found to be increased compared to the children who had exercised less than 1000 hours. The differences were statistically significant.

Conclusion: Ventricular repolarization got affected in child athletes, and the duration of exercise determined the degree of cardiac change.

Keywords: Athlete, children, echocardiogram, electrocardiogram, sports

An athlete's heart is a constellation of structural and functional changes that occur in the heart due to long-term physical activity.[1,2] Accordingly, changes in electrocardiograms (ECGs) and echocardiograms (ECHOs) are commonly observed in athletes.[3] An important part of the young population participates in competitive or recreational sports activities. Electrocardiograms provide important and diagnostic information about cardiovascular diseases that cause sudden cardiac death in sports. Physicians are frequently asked to interpret an ECG for cardiovascular evaluation of an athlete, and this interpretation is usually made according to the general criteria used for the non-athletic population.[4] Therefore, it is useful to know the spectrum of ECG changes in order to differentiate between normal and pathological conditions of the heart in young athletes.[5]

Electrocardiogram changes in young athletes can be divided into 2 groups. In group 1, common and training-related changes include sinus bradycardia, sinus arrhythmia, first-degree atrioventricular block, early repolarization, left ventricular hypertrophy, incomplete right bundle branch block, ST-segment (between the end of the QRS complex and the beginning of the T wave) elevation, high T waves, and right or left atrial enlargement. Electrocardiogram changes in group 2 may indicate underlying cardiovascular disease such as inverted T waves using ≥2 consecutive leads, ST-segment depression, Brugada-like early repolarization, pathological Q waves, left atrial enlargement, left axis deviation/left anterior hemiblock, right axis deviation/right posterior hemiblock, intraventricular conduction defects (complete bundle branch block), ventricular pre-excitation, long and short QTc intervals.[4,5] Changes in group 2 may indicate underlying cardiovascular disease, hereditary cardiomyopathies, or ion channel diseases which predispose to sudden cardiac death.[6]

We aimed to evaluate ECG changes in pediatric athletes. Our study may provide more information on the changes in heart function that could be predictive of cardiac death during sports.

Methods

The study was approved by the Ethics Committee of Prof. Dr. Cemil Taşçıoğlu City Hospital (Approval Date: August 27, 2019, Approval number: 1419). Patients have given their informed consent for participation in the research study.

In this study, we analyzed the ECGs and ECHOs of 136 child athletes who were admitted to the Pediatric Cardiology Clinic in Prof. Dr. Cemil Taşçıoğlu City Hospital for routine examination between February 2019 and July 2019. The control group included 90 healthy children who were referred to the Pediatric Cardiology Clinic for regular check-ups and had no abnormalities during a cardiac examination, ECG, and ECHO. Children with family history of a cardiac disease were excluded from the study for both groups. Electrocardiograms were performed at 12-lead, 25 mm/sec speed and 10 mm/mV calibration.

The age, sex, weight, height, and body mass index (BMI, kg/m^2) data of all the participants were recorded. Sports types, training duration (years), frequency (days per week), and exercise time (hours per day) were recorded in athletes group. Heart rate, rhythm, axis, P wave duration, PR interval (from the beginning of the P wave to the beginning of the Q wave), QRS complex duration

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Corresponding author: Melis Akpınar Gözetici, Department of Pediatrics, Sancaktepe Şehit Prof. Dr. İlhan Varank Training and Research Hospital, İstanbul, Turkey **e-mail:** melisakpinar1990@hotmail.com
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(from the beginning of the Q wave to the end of the S wave), V1-S (S amplitude in lead V1) and V5-R (R amplitude in lead V5) wave amplitude sum and ratio, V1-S and V6-R (R amplitude in lead V6) wave amplitude sum and ratio, QT interval (from the beginning of the Q wave to the end of the T wave), QTc (calculated with Bazett formula), QTd (QT dispersion; the difference between the minimum and maximum QT in all leads), QTcd (QTc dispersion: the difference between the minimum and maximum QTc in all leads in the ECG), JT interval (from the end of the S wave to the end of the T wave), JTc (calculated with Bazett formula), Tp-e interval (from the peak of the T wave and the end of the T wave), inverted T waves, presence of early repolarization pattern (ERP), ECHO, left ventricular internal dimension in diastole (LVIDd), left ventricular internal dimension in systole (LVIDs), and fractional shortening (FS) were recorded and compared to the control group. The same parameters were compared in athletes who had exercised more than 1000 hours and less than 1000 hours.

All ECGs were analyzed by a pediatric cardiologist and a pediatrician, blinded to all clinical details, using a millimeter ruler and calipers. Intra- and interobserver variability for the measurements was determined as <5%. Measurements were not taken in ECG leads which have high artifacts and where the starting or finishing point of the waves could not be selected.

Statistical analyses

Quantitative data of groups were analyzed with *t* tests and qualitative data were analyzed with chi-square test using Statistical Package for Social Sciences (IBM SPSS Corp., Armonk, NY, USA) 22.0 software. $P < .05$ was considered as statistically significant.

Results

In the athletes group of 136 children and control group of 90 children, male/female ratio was 1.51 and 1.1, respectively. There was no statistically significant difference in terms of gender ($P = .3$). In the athletes group, 83 children played football, 16 played basketball, 10 played volleyball, 10 boxed, 6 participated in athletics, and 11 participated in karate. The mean age was 13.1 ± 2.2 years in the athletes group and 12.8 ± 1.98 years in the control group ($P = .33$). Also, there were no statistically significant differences between the groups in terms of the mean weight, height, and BMI (*P* values were 0.71, 0.16, and 0.16, respectively).

The mean heart rate was 75.2 ± 13.55 beats per minute (bpm) in the athletes group and 83.9 ± 12.72 bpm in the control group. The difference between 2 groups was statistically significant ($P = .001$).

Electrocardiograms showed there were no statistically significant differences between the 2 groups in terms of P wave duration, PR interval, QRS interval, the sum of V1-S + V5-R wave amplitude, V1-S/V5-R amplitude ratio, sum of V1-S + V6-R wave amplitude, V1-S/V6-R amplitude, QTc, QTcd, JTc, presence of ERP, and FS. These values are presented in Table 1.

Statistically significant differences were found between the 2 groups regarding the QRS amplitude, QT, QTd, JT, Tp-e, LVIDd, LVIDs. These values are presented in Table 2. There were no effect of the type of sports on these differences.

Measurements of 85 athletes who exercised less than 1000 hours were compared to 51 athletes who exercised more than 1000 hours. Statistically significant differences were found in terms of heart rate, PR, QRS, V1-S + V5-R, LVIDs, and the values were shown in Table 3.

Table 1. P, PR and QRS Intervals, V1-S + V5-R, V1-S/V5-R, V1-S + V6-R, V1-S/V5-R, QTc, QTcd, JTc, ERP, and FS Values in Groups*

	Athletes	Control	*P*
P duration (ms)	96.2 ± 12.61	95.8 ± 7.91	.75
PR interval (ms)	135.8 ± 19.72	134.1 ± 14.9	.49
QRS interval (ms)	86.77 ± 10.4	85.8 ± 8.62	.48
V1-S + V5-R (mm)	21.4 ± 7.83	20.6 ± 5.92	.43
V1-S/V5-R	0.54 ± 0.23	0.73 ± 0.17	.18
V1-S + V6-R (mm)	18.8 ± 7.04	18.3 ± 6.09	.57
V1-S/V6-R	1.18 ± 0.54	1.48 ± 0.83	.74
QTc interval (ms)	423.6 ± 25.48	427.06 ± 19.13	.28
QTcd (ms)	32.4 ± 15.62	29.2 ± 15.66	.13
JTc interval	324.1 ± 30.18	326.89 ± 20.33	.45
Presence of ERP (n)	21	18	.30
FS	40.68 ± 4.11	40.7 ± 4.38	.98

*Values are given as mean ± standard seviation. n, number; QTc, corrected QT; QTcd, corrected QT dispersion; JTc, corrected JT; ERP, early repolarization pattern; FS, fractional shortening.

Table 2. QRS Amplitude, QT, QTd, JT, Tp-e, LVIDd, and LVIDs Values in Groups*

	Athletes	Control	*P*
QRS amplitude (mm)	14.9 ± 4.69	13.5 ± 3.71	.021
QT interval (ms)	382.0 ± 33.48	363.5 ± 21.46	<.001
QTd (ms)	29.6 ± 14.63	25.0 ± 13.64	.01
JT interval (ms)	294.4 ± 35.54	277.8 ± 21.04	<.001
Tp-e interval (ms)	90.3 ± 18.43	79.4 ± 17.18	<.001
LVIDd (mm)	47.4 ± 5.27	44.8 ± 4.48	<.001
LVIDs (mm)	28.4 ± 4.50	26.3 ± 2.92	<.001

*Values are given as mean ± standard deviation. QTd, QT dispersion; Tp-e, Tpeak-end; LVIDd, left ventricular internal dimension in diastole; LVIDs, left ventricular internal dimension in systole.

Discussion

The ECG parameters of all children included in our study were within normal ranges according to their age, but there were significant differences between the athletes and the control groups. Changes in heart rate, increased left ventricular muscle mass and volume, and increased stroke volume are the characteristics of the athlete's heart at rest.[1,2] The growth of heart sizes contributes to the decrease in heart rate.[7] In our study, the heart rate was 75.2 bpm in the athletes group and 83.9 bpm in the control group and the difference was significant ($P < .001$).

Zdravkovic et al[8] examined the ECGs of child football players; P, S, R, T wave amplitude, V1-2 S + V5-6 R, QRS interval, T wave duration, QTc interval, LVIDs and LVIDd were significantly higher than control group. In our study, QRS amplitude, LVIDd and LVIDs were higher in the athletes group. These findings could be the early ECG markers of physiological left ventricular remodeling in young athletes.

Heart rate was lower, and the mean PR and QRS intervals and LVIDs were higher in the children who exercised more

Tablo 3. Heart Rate, PR, QRS Interval, V1-S+V5-R, V1-S+V6-R, and LVIDs Values of Athletes Who Exercise More Than 1000 Hours and Less Than 1000 Hours Totally

	More Than 1000 h (n = 85)	Less Than 1000 h (n = 51)	*P*
Heart rate (bpm)	77.2 ± 14.15	71.9 ± 11.86	.02
PR interval (ms)	131.8 ± 19.51	142.6 ± 18.3	.002
QRS interval (ms)	85.44 ± 9.82	89.0 ± 11.05	.04
V1-S+V5-R (mm)	20.0 ± 7.28	23.8 ± 8.26	.007
V1-S+V6-R (mm)	17.6 ± 7.07	20.8 ± 6.56	.01
LVIDs (mm)	27.8 ± 4.67	29.5 ± 4.01	.02

*Values are given as mean ± standard deviation. bpm, beats per minute; LVIDs, left ventricular internal dimension in systole.

than 1000 hours compared to those who exercised less than 1000 hours. We used the Sokolow–Lyon criteria for left ventricular hypertrophy.[9] The mean V1-S+V5-R and V1-S+V6-R amplitudes were higher in the more than 1000 hours group compared to the less than 1000 hours group. Exercise duration may impact cardiac development of child athletes.

Prolonged cardiac repolarization is associated with susceptibility to torsades de pointes, which can lead to ventricular tachyarrhythmia or ventricular fibrillation.[10] Cardiac repolarization can be assessed by QT, QTc, QTd, and Tp-e interval.[11] Since JT interval and JTc are not affected by QRS interval, they are considered to be more valuable indices for predicting ventricular repolarization, and their sensitivity and specificity are higher than QT and QTc.[12] In our study, JT interval was longer in the athletes group ($P < .001$). However, the mean JTc was 324.1 ms in the athletes group and 326.89 ms in the control group and the difference was not statistically significant ($P = .45$). In our study, QT and JT were found to be longer in the athletes group, but when the measurements were corrected according to the heart rate, QTc and JTc were not different between the 2 groups. These results may be attributed to the athletic low heart rate.

QT dispersion shows the difference in regional ventricular repolarization changes.[13] In pathological left ventricular hypertrophies, QTd increases and can be used as an indicator of the tendency to arrhythmia since it is a useful and non-invasive method.[14] Jordaens et al[15] found that QT dispersion in athletes with a history of arrhythmic events (96 ± 51 millisecond) was significantly higher than healthy athletes (57 ± 22 millisecond) with similar left ventricular structure. In our study, pathological left ventricular hypertrophy was not detected but the mean QTd was found to be increased in athletes ($P = .01$). These results suggest that it is important to follow up the athletes with high QTd in terms of arrhythmia. It has been suggested that ventricular transmural repolarization causes arrhythmia in Brugada, short QT, and long QT syndromes.[16] Tp-e interval is accepted as an indicator of the total distribution (transmural, apicobasal, global) of ventricular repolarization.[11] In our study, the mean Tp-e was higher in the athletes group ($P < .001$). Based on these results, sports may lead to regional repolarization changes in children.

Repolarization changes including ST elevation and tall T waves are present in 60% of athletes.[5,7] Early repolarization pattern is considered to be an idiopathic and benign ECG phenomenon, occurring in 1-2% of healthy children and usually in men.[17] Early repolarization pattern is likely to be associated with vagal tonus because it occurs when heart beats slowly and disappears after exercising or spontaneously.[18] In the present study, ERP is defined in 21 of athletes group and 18 of control group and the difference was not statistically significant ($P = .3$).

The main limitation of our study is the small number of participants. Future larger prospective studies are needed with baseline ECGs and ECHOs of the athletes.

According to these results, ventricular repolarization may be affected in athletic children. Sports may lead to regional repolarization changes. Prolonged cardiac repolarization is associated with susceptibility to arrhythmias. The duration of training determines the degree of cardiac change. These results suggest that it is important to follow up the athletes.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Okmeydanı Training and Research Hospital (Date: August 27, 2019, No: 1419).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

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References

1. Bahlmann E, Kuck KH, Nienaber CA. Athlete's heart and hypertrophic cardiomyopathy: contribution on clinical and morphologic differentiation. *Dtsch Med Wochenschr*. 2015;140(15):1158-1164. [CrossRef]
2. Albaeni A, Davis JW, Ahmad M. Echocardiographic evaluation of the Athlete's heart. *Echocardiography*. 2021;38(6):1002-1016. [CrossRef]
3. Baggish AL, Wood MJ. Athlete's heart and cardiovascular care of the athlete: scientific and clinical update. *Circulation*. 2011;123(23):2723-2735. [CrossRef].
4. Corrado D, Pelliccia A, Heidbuchel H, et al. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. *Eur Heart J*. 2010;31(2):243-259. [CrossRef]
5. Machado M, Vaz Silva M. Benign and pathological electrocardiographic changes in athletes. *Rev Port Cardiol*. 2015;34(12):753-770. [CrossRef]
6. Corrado D, McKenna WJ. Appropriate interpretation of the athlete's electrocardiogram saves lives as well as money. *Eur Heart J*. 2007;28(16):1920-1922. [CrossRef]
7. Papadakis M, Basavarajaiah S, Rawlins J, et al. Prevalence and significance of T-wave inversions in predominantly Caucasian adolescent athletes. *Eur Heart J*. 2009;30(14):1728-1735. [CrossRef]
8. Zdravkovic M, Milovanovic B, Hinic S, et al. Correlation between ECG changes and early left ventricular remodeling in preadolescent footballers. *Physiol Int*. 2017;104(1):42-51. [CrossRef]
9. Su FY, Li YH, Lin YP, et al. A comparison of Cornell and Sokolow-Lyon electrocardiographic criteria for left ventricular hypertrophy in a military male population in Taiwan: the Cardiorespiratory fitness and hospitalization events in armed forces study. *Cardiovasc Diagn Ther*. 2017;7(3):244-251. [CrossRef]
10. Martínez JP, Laguna P, Olmos S, Pahlm O, Pettersson J, Sörnmo L. Assessment of QT-measurement accuracy using the 12-lead

electrocardiogram derived from EASI leads. *J Electrocardiol*. 2007;40(2):172-179. [CrossRef]
11. Kors JA, van Eck HJR, van Herpen G. The meaning of the Tp-Te interval and its diagnostic value. *J Electrocardiol*. 2008;41(6):575-580. [CrossRef]
12. Tabatabaei P, Keikhavani A, Haghjoo M, et al. Assessment of QT and JT intervals in patients with left bundle branch block. *Res Cardiovasc Med*. 2016;5(2):e31528. [CrossRef]
13. Verrier RL, Nearing BD, D'Avila A. Spectrum of clinical applications of interlead ECG heterogeneity assessment: from myocardial ischemia detection to sudden cardiac death risk stratification. *Ann Noninvasive Electrocardiol*. 2021;26(6):e12894. [CrossRef]
14. Malik M, Batchvarov VN. Measurement, interpretation and clinical potential of QT dispersion. *J Am Coll Cardiol*. 2000;36(6):1749-1766. [CrossRef]
15. Jordaens L, Missault L, Pelleman G, Duprez D, De Backer G, Clement DL. Comparison of athletes with life-threatening ventricular arrhythmias with two groups of healthy athletes and a group of normal control subjects. *Am J Cardiol*. 1994;74(11):1124-1128. [CrossRef]
16. Antzelevitch C. T peak-T end interval as an index of transmural dispersion of repolarization. *Eur J Clin Investig*. 2001;31(7):555-557. [CrossRef]
17. Noseworthy PA, Weiner R, Kim J, et al. Early repolarization pattern incompetitive athletes: clinical correlates and the effects of exercise training. *Circ Arrhythm Electrophysiol*. 2011;4(4):432-440. [CrossRef]
18. Boineau JP. The early repolarization variant: an electrocardiographic enigma with both QRS and J-STT anomalies. *J Electrocardiol*. 2007;40(1):3.e1-3.10. [CrossRef]