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Early electrocardiogram changes in highly trained preadolescent football players

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Abstract

Objective. To assess the early electrocardiogram (ECG) changes induced by physical training in preadolescent professional football players. **Design and methods.** Ninety-four highly trained male football players (mean age — 12.85 ± 0.84 years) competing in the Serbian Football League (at least 7 training hours/week) and 47 age-matched healthy male controls were enrolled in the study. They were screened by ECG and echocardiography at a tertiary referral cardiocentre. The control group had sedentary life style (less than 2 training hours/week). Characteristic ECG intervals and ECG voltage were compared and reference range was given for preadolescent footballers. **Results.** Highly significant differences between preadolescent athletes and sedentary controls were registered in all ECG parameters: P wave voltage ($p < 0.001$), S wave (V1 or V2 lead) voltage ($p < 0.001$), R wave (V5 and V6 lead) voltage ($p < 0.001$), ECD sum of the S1.2 + V5.6 ($p < 0.001$), T wave voltage ($p < 0.001$), QRS complex duration ($p < 0.001$), T wave duration ($p < 0.001$), QTc interval duration ($p < 0.001$) and R/T ratio ($p < 0.001$). No differences were registered in PQ interval duration between these two groups ($p > 0.05$). QTc interval duration in athletes was not very strongly, but indeed positively correlated with left atrium dilatation, left ventricular (LV) end-systolic and end-diastolic dimensions, LV myocardial index (LVMI), LVM/body surface area $(BSA)^{1.5}$ and $LVM/h^{2.7}$ indices. There was no correlation between QTc interval duration and LVM as well as LV wall thickness. **Conclusions.** ECG changes are present in the early stage of athletes' heart remodeling. QTc prolongation could be the early ECG marker of physiological LV remodeling in young preadolescent footballers.

Key words: athletes, cardiology, electrocardiography, heart, footballers, preadolescence

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Ранние изменения электрокардиограммы у профессиональных футболистов предподросткового возраста

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Резюме

Цель исследования — оценить ранние изменения электрокардиограммы (ЭКГ), возникшие на фоне физических нагрузок, у профессиональных футболистов предподросткового возраста. **Материалы и методы.** В исследование было включено 94 мальчика (средний возраст — 12,85 ± 0,84 года), профессионально занимающихся футболом в составе Сербской футбольной Лиги (не менее 7 часов тренировок в неделю), и 47 не занимающихся профессиональным спортом здоровых мальчиков того же возраста. Всем в качестве скринингового обследования были проведены регистрация ЭКГ и эхокардиографическое исследование в кардиологических центрах третьей ступени. Здоровые дети из контрольной группы вели малоподвижный образ жизни (менее 2 часов тренировок в неделю). Проведено сравнение общепринятых ЭКГ-показателей — интервалов и вольтажных характеристик, и определены референсные значения у профессиональных футболистов предподросткового возраста. **Результаты.** Между детьми, профессионально занимающимися футболом и ведущими малоподвижный образ жизни, выявлены существенные различия по всем оцениваемым показателям ЭКГ: по амплитуде зубца P ($p < 0,001$), амплитуде зубца S (в отведении V1 или V2) ($p < 0,001$), амплитуде зубца R (в отведении V5 и V6) ($p < 0,001$), алгебраической сумме зубцов S1,2 + V5,6 ($p < 0,001$), амплитуде зубца T ($p < 0,001$), длительности комплекса QRS ($p < 0,001$), длительности зубца T ($p < 0,001$), длительности интервала QTc ($p < 0,001$) и отношению зубцов R/T ($p < 0,001$). Различий в длительности интервала PQ между группами выявлено не было ($p > 0,05$). Длительность интервала QTc у спортсменов положительно коррелировала с размером левого предсердия, с конечно-систолическим и конечно-диастолическим размерами левого желудочка (ЛЖ), индексом массы миокарда (ММ) ЛЖ, индексами ММЛЖ/ППТ (площадь поверхности тела)[1,5] и ММЛЖ/рост[2,7], хотя связь не была очень сильной. Длительность интервала QTc не коррелировала с ММЛЖ и толщиной стенки ЛЖ. **Выводы.** Изменения показателей ЭКГ отмечаются у спортсменов на очень ранних стадиях ремоделирования. Удлинение QTc может рассматриваться как ранний предиктор физиологического ремоделирования ЛЖ у профессиональных футболистов предподросткового возраста.

Ключевые слова: спортсмены, кардиология, электрокардиография, сердце, футболисты, детский возраст.

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Introduction

Electrocardiogram (ECG) and echocardiographic changes in athletes are common and usually reflect structural and electrical remodeling of the heart as an adaptation to regular physical training and hemodynamic changes that alter the loading conditions of the heart, causing the athlete's heart syndrome [1]. However, the level and duration of training or competition, aerobic capacity and type of sports activity play an important role in the extent of physiological changes of athlete's heart syndrome [2]. The most of health problems associated with increased risk of sudden cardiac death (SCD), such as cardiomyopathies and primary rhythm disorders due to the electrical damages, are suggested by abnormal findings present on an ECG. ECG interpretation in athletes requires a very detailed analysis to properly define physiological changes related to athlete's heart from findings suggestive of an underlying cardiac disease [3]. The main goal of the ECG evaluation in athletes is to describe ECG as: (1) «normal» — no further evaluation needed or (2) «abnormal» — further evaluation needed. Abnormal findings are unrelated to regular training and also found in underlying pathological cardiac conditions. These include findings suggestive of cardiomyopathy such as T-wave inversion, ST depression, pathological Q-waves, left axis deviation and conduction delays and findings suggestive or diagnostic of primary electrical diseases such as long QT syndrome and Wolff-Parkinson-White syndrome.

Several recommendations elucidated pathological ECG signs in athletes [4–6]; however, data regarding preadolescent athletes are quite limited [7–9]. Several studies concluded that there is early left ventricle remodeling in preadolescent footballers, but data regarding early ECG changes are missing [10–12]. In the following study the tested hypothesis was: there are differences in ECG parameters between two compared groups in early preadolescent period, elite football players and age-matched sedentary controls induced by specific athlete heart syndrome. The second aim was to investigate QTc interval correlation with echocardiographic parameters in elite preadolescent football players. Finally, the third aim of this study is to address the relative lack of data in the literature data regarding normal values of ECG parameters in preadolescent population of football players.

Design and methods

A group of 94 Caucasian elite male footballers aged 12.85 (0.84) years (age range 12–14 years), all members of the National Football Premier League clubs, were enrolled. The control group consisted of 47 healthy male age-matched sedentary controls, who were not exercising regularly (sport-training for not more than 2 hours a week). None of the participants had any symptoms attributable to cardiovascular disease. No subject was taking any form of prescribed drug treatment. Physical examination was without any pathological findings in all participants. They all were normotensives and nonsmokers. All athletes had been regularly engaged in active training for at least three years and were in their active training season. They had, on average, 9 hours of weekly training which included: 5 hours specific football training, 2 hours anaerobic dynamic training, 1 hour strength training and 1 hour aerobic endurance activities. The sample size was calculated to have a power more than 80% to detect a difference at $p < 0.05$ [12].

Echocardiographic evaluation was performed by the same experienced cardiologist who was blind to the subject's training group, on every occasion using Acuson Sequoia computed sonography platform with a probe frequency 3.5 MHz vector array format transducer following the recommendations of the American Society of Echocardiography [10]. The images were obtained in the parasternal long and short axis, in left lateral position and also in the four chamber view and then analyzed off-line. Both M–Mode and cross sectional studies were performed. The measurements of the left atrium (LA), aortic root (AO), left ventricular end diastolic dimension (LVED), left ventricle end systolic dimension (LVES), left ventricle posterior wall diastolic dimension (PWd), interventricular septal diastolic dimension (IVSd), were done in the parasternal long axis view, by the average of 3 consecutive cardiac cycles with concomitant ECG and the average was calculated. Left ventricular ejection fraction (EF) was calculated by Simpson's rule. Left ventricular mass (LV mass) was calculated using the method described by Devereux et al. [13].

$$LVM = 1.04 \times [(LVED + PWd + IVSd) \times 3 — LVED \times 3] — 13.6\ g$$

Left ventricular mass index (LVMI) was calculated by standard dividing LV mass by BSA [13].

All heart valves were assessed by standard technique in order to exclude significant valvular and subvalvular obstruction and regurgitation. Valve regurgitation severity was evaluated according to the recommendations of the American Society of Echocardiography (ASE) Guidelines [9].

As LVM is known to vary with body size and composition, normalization of LV dimensions according to body size is very important in comparisons between different subjects groups. In children and adolescents increased cardiac size is directly proportional to the increases of body height, so these adjustments according to body size were done for comparison of cardiac dimensions: LV mass findings were adjusted to BSA1.5 and LVM was additionally adjusted to height2.7 [14].

Standard 12-lead electrocardiogram (EGC) was recorded using a Nihon Cohden recorder with a paper speed of 25 mm/s and amplification of 0.1 mV/mm. The QT interval was measured in all leads from the onset of QRS complex to the end of T wave, defined as the intersection of isoelectric line and the tangent of the maximal downward limb of the T wave [15]. The QTc values were derived using Bazett's formula, which has been most widely used in all large studies evaluating patients with LQTS [16]. The Bazett correction is commonly used in QTc interval investigations and involves dividing the uncorrected QT (in seconds) by the square root of the RR interval (in seconds). The limitations of this method are over-correction at faster heart rates (lower RR intervals) and under-correction at slower heart rates (higher RR intervals).

All ECGs were analyzed independently by two independent cardiologists with a clinical and academic interest in ECGs, blinded to all clinical details of the subjects, using a millimeter ruler and calipers [17].

Statistical analysis

Continuous data are expressed as mean (SD), with 5th and 95th percentile ranges to facilitate comparison with the data belonging to the controls. Statistical analysis was carried out using unpaired t-tests between groups. Statistical significance is stated as $p < 0.05$.

Results

Selected physical characteristics of the footballers and the controls are shown in Table 1.

The footballers had similar height as the control group, but significantly smaller weight and BSA. Heart rate was significantly lower in athletes then in control subjects. Values of systolic blood pressure were similar in both groups, but diastolic blood pressure was higher in athletes, nevertheless normal.

Table 2 shows comparison of the ECG findings in 94 preadolescent footballers and 47 age-matched non-athletes (the mean and SD).

Highly significant differences between preadolescent athletes and sedentary controls were registered in all ECG parameters: P wave voltage ($p < 0.001$), S wave (V1 or V2 lead) voltage ($p < 0.001$), R wave (V5 and V6 lead) voltage

Table 1

THE CHARACTERISTICS OF THE 94 FOOTBALLERS AND 47 AGE-MATCHED NON-ATHLETES (THE MEAN AND SD)

	Footballers	Non-athletes	p
Age (years)	12.85 (0.84)	12.85 (0.86)	NS
Height (cm)	159.36 (10.65)	162.71 (13.09)	NS
Weight (kg)	48.27 (10.62)	58.28 (13.07)	< 0.001
BSA (m^2)	1.45 (0.20)	1.61 (0.24)	< 0.001
BMI (kg/m^2)	18.75 (1.92)	21.59 (1.86)	< 0.001
HR (bpm)	83.49 (14.50)	88.8 (5.19)	< 0.001
Systolic blood pressure (mmHg)	109.95 (8.08)	108.19 (6.71)	NS
Diastolic blood pressure (mmHg)	65.74 (7.89)	60.75 (5.80)	< 0.001

Legend: BSA — body surface area; BMI — body mass index; HR — heart rate; ** — p < 0.001 compared to controls; NS — not significant.

Table 2

COMPARISON OF THE ELECTROCARDIOGRAM FINDINGS IN 94 PREADOLESCENT FOOTBALLERS AND 47 AGE-MATCHED NON-ATHLETES (THE MEAN AND SD)

	Footballers	Non-athletes	t	p
HR (bpm)	72.22 (5.18)	90.00 (5.23)	–19.14	< 0.001**
P wave voltage	1.96 (0.16)	1.34 (0.46)	11.81	< 0.001**
S wave voltage (V1 or V2 lead)	12.11 (2.61)	10.66 (2.09)	3.307	< 0.001**
R wave voltage (R5 or R6)	17.21 (2.35)	15.28 (2.24)	4.687	< 0.001**
S1.2 + V5.6	29.42 (3.91)	24.89 (3.59)	5.189	< 0.001**
T wave voltage	8.10 (2.33)	4.15 (1.00)	11.107	< 0.001**
PQ interval duration	174.02 (3.57)	162.84 (1.56)	–2.064	< 0.05
QRS complex duration	82.44 (1.30)	76.01 (0.71)	3.186	< 0.001**
T wave duration	173.82 (2.03)	205.14 (2.62)	–7.802	< 0.001**
QTc interval duration	419.89 (13.07)	399.78 (13.27)	8.566	< 0.001**
R/T	2.29 (0.72)	3.89 (1.06)	–10.500	< 0.001**

Legend: ** — p < 0.001 compared to controls; HR — heart rate.

Table 3

THE REFERENCE VALUES OF ELECTROCARDIOGRAM PARAMETERS FOR PREADOLESCENT FOOTBALLERS

	Reference values	
Electrocardiographic parameters	**Footballers**	**Non-athletes**
HR (beats/min)	65–82	82–99
P wave voltage (mV)	1.5–2.0	0.5–2.0
S wave voltage (V1 or V2) (mV)	8.0–16.25	8.0–14.0
R wave voltage (R5 or R6) (mV)	14.0–22.0	11.0–19.0
Sokolow-Lyon index (mV)	24.0–36.25	19.4–32.0
T wave voltage (mV)	5.0–12.0	3.0–6.0
PQ interval duration (msec)	140–220	120–200
QRS complex duration (msec)	60–110	60–80
T wave duration (msec)	160–220	160–240
QTc interval duration	397.5–440.0	380.0–420.0
R/T	1.42–3.62	2.08–5.67

Legend: HR — heart rate.

($p < 0.001$), ECD sum of the S1.2 + V5.6 ($p < 0.001$), T wave voltage ($p < 0.001$), QRS complex duration ($p < 0.001$), T wave duration ($p < 0.001$), QTc interval duration ($p < 0.001$) and R/T ratio ($p < 0.001$). No differences were noticed in PQ interval duration between these two groups ($p > 0.05$).

All participants had normal values of QTc interval. Mean QTc interval in athletes in rest was significantly longer 419.89 ± 13.07 msec, compared to mean QTc in the control sedentary group — 399.78 ± 13.27 msec ($p < 0.001$). The mean and SD of the QTc values in footballers as well as in non-athletes are shown in Table 2, together with correlation of these parameters to echocardiographic measurements.

QTc interval duration in athletes had not very strong, but indeed positive correlation to left atrium dilatation, LV end-systolic and end-diastolic dimensions, LVMI, LVM/BSA1.5 and LVM/h2.7 indexes. There was no correlation between QTc interval duration and LVM as well as LV wall thickness.

Discussion

The data indicate that all ECG parameters are highly significantly different in preadolescent footballers compared to age-matched sedentary controls. None of the clearly pathological ECG signs was detected neither in preadolescent footballers nor in sedentary controls. It was not surprising that the resting heart rates of the athletes were faster than the typically reported heart rate in the previous studies, since this was the unique age group of very young athletes.

Normal ECGs in adult include common, training-related findings in athletes such as high QRS amplitude meeting voltage criteria for left ventricular hypertrophy, early repolarisation, sinus bradycardia, sinus arrhythmia and 1° atrioventricular block [18–20]. None of these finding were registered in our group. The reason is very young age of the investigated athletes.

In athlete population the QTc interval prolongation was demonstrated through a huge number of studies [21–23]; in all of them there were also left ventricular hypertrophy with increased left ventricle wall thickness, suspected to be the cause of the prolongation. But increased left ventricle wall thickness is not common in preadolescent period and consequently QTc prolongation is less likely to be expected [24, 25].

However, still our data indicate no correlation between QTc interval duration and LV wall thickness, analysis of specific LV mass indices

Table 4

COMPARISON OF THE RESTING ECHOCARDIOGRAPHIC FINDINGS IN 94 FOOTBALLERS AND 47 AGE-MATCHED NON-ATHLETES AND CORRELATION BETWEEN QTC INTERVAL DURATION AND ECHOCARDIOGRAPHIC PARAMETERS IN ADOLESCENT YOUNG FOOTBALLERS (THE MEAN AND SD)

	Footballers	Non-athletes	p	QTc correlation	§
Ao (mm per $BSA^{0.5}$)	21.87 (2.08)	15.65 (1.36)	< 0.01	0.478	< 0.05
LA (mm per $BSA^{0.5}$)	23.18 (2.07)	20.15 (2.87)	< 0.01	0.221	< 0.01
LVED (mm per $BSA^{0.5}$)	38.72 (2.53)	35.68 (2.54)	< 0.01	0.351	< 0.01
LVES (mm per $BSA^{0.5}$)	25.83 (2.58)	20.75 (2.30)	< 0.01	0.374	< 0.01
IVSd (mm per $BSA^{0.5}$)	7.08 (0.70)	6.53 (0.81)	НЗ	0.089	НЗ
PWd (mm per $BSA^{0.5}$)	6.82 (0.73)	6.46 (0.80)	НЗ	–0.045	НЗ
LVM (g)	160.14 (33.14)	149.59 (34.01)	НЗ	0.096	НЗ
LVMI (g per BSA)	109.79 (15.04)	92.84 (18.29)	< 0.01	0.235	< 0.01
LVM/$BSA^{1.5}$ (g per $BSA^{1.5}$)	91.55 (13.86)	73.73 (16.54)	< 0.01	0.339	< 0.01
LVM/$h^{2.7}$ (g per $h^{2.7}$)	45.78 (9.47)	40.65 (9.29)	< 0.01	0.298	< 0.01
QTc (msec)	419.89 (13.27)	399.78 (13.07)	< 0.01	/	< 0.01

Legend: BSA — body surface area; BMI – body mass index; HR — heart rate; Ao — aortic root diameter; LA — left atrium; LVED — left ventricular end-diastolic dimension; LVES — left ventricular end-systolic dimension; IVSd — ventricular septal thickness (diastole); PWd — ventricular posterior wall thickness (diastole); LVM — left ventricular mass; LVMI — left ventricle mass index; h-height; * — $p < 0.01$ compared to controls; § — $p < 0.01$ correlation of echocardiographic parameters and QTc interval duration; NS — not significant.

revealed that correlation between these indices and QTc prolongation could be the explanation for the QTc prolongation [26, 27]. Furthermore, QTc prolongation could be the early ECG marker of physiological LV remodeling in young preadolescent footballers, without any other standard ECG and echocardiographic signs of early LV hypertrophy. This fact could be explained by a different pattern of left ventricle remodeling in preadolescent period, where LV wall thickness increase cannot usually be seen and the predominant characteristic is left ventricle dilatation. In our opinion QTc prolongation in athletes is related to the early cardiac remodeling and can be seen even after a short period of training; nevertheless recommended normal values of QTc interval in young preadolescent footballers should be expected [28, 29].

Limitations

The study is limited to Serbian Caucasian preadolescent footballers and differences with other races can occur [28, 30]. Although further study is necessary, we expect athletes with different sports to have similar findings [25, 29].

Conclusions

In summary, the study showed that there are highly significant differences in ECG interval between preadolescent footballers and age-matched controls. A prolongation of QTc interval in highly trained preadolescent footballers compared to the QTc interval in preadolescents with sedentary life style, correlates with specific LV mass indices. However, this prolongation is still within recommended values. QTc prolongation could be the early ECG marker of physiological LV remodeling in young preadolescent footballers, without any other standard ECG and echocardiographic signs of early LV hypertrophy.

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