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EXAMINING THE EFFECT OF THE TYPE OF SPORT ON THE FREQUENCY OF ELECTROCARDIOGRAPHIC CHANGES IN MEDICAL STUDENTS INVOLVED IN SPORTS

Abstract: Continuous physical activity leads to a series of adaptive changes to athletes' cardiovascular system, collectively called Athlete's heart. Recognizing such physiological ECG changes and distinguishing them from the pathological myocardium-related findings, play an important role in sudden cardiac death prevention among athletes.

The aim of our study was to examine the effect of the type of sport on the frequency of electrocardiographic changes between two groups of subjects, football and volleyball players.

The study included 47 subjects, students of the Faculty of Medicine, University of Belgrade, divided into two groups depending on type of sport they play. The first group consisted of 29 volleyball players, while the second group consisted of 18 football players. Anthropometric parameters: body height (BH), body weight (BW), body mass index (BMI), body fat percentage (%BF) were measured first. Resting electrocardiographic test was performed in supine position, using twelve-lead electrocardiograph. From obtained electrocardiograms (ECG), using the Seattle criteria for interpretation of ECG findings in athletes, following parameters were analyzed: heart rate, heart rhythm, rhythmicity, respiratory arrhythmia, cardiac axis, duration and amplitude of individual waves, segments and intervals, QTc, right and left atrial enlargement, isolated voltage criteria for left and right ventricular hypertrophy, incomplete right bundle-branch block, first degree AV block, second degree AV block-Mobitz type I (Wenckebach), and T wave inversion. Statistical analysis was performed using paired T-test and Chi square test, within the SPSS package.

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Results of the study showed higher values of amplitude of P wave in the V1 lead among football players (p=0.015), alongside significant difference in frequency of T wave inversion in leads V1-V3 (p=0.048). Volleyball players demonstrated significantly higher frequency of left atrial enlargement (p=0.019).

Based on presented results, we can conclude that observed ECG changes indicate that different types of sports may lead both to changes in electrical activity of cardiac conduction system and myocardium.

Keywords: athlete's heart, physical activity, physical exercise, electrocardiography, Seattle criteria

Introduction

Physical activity is defined as any movement of the body caused by the skeletal muscle contraction, which leads to energy consumption. Exercise is a type of physical activity composed of planned, defined and repetitive motions that are performed with the aim of improving or maintaining one or more components of physical ability. [1] Organized physical activity, oriented towards achieving results and regulated by a series of rules, is defined as a sport. Sports activity mainly has a competitive character - professional sports (athletes) or amateur sports (recreational sports). Professional athletes train more and on a higher intensity than recreational athletes. [2] Some positive aspects of regular exercising include the following: proper growth and development of children [3], reduced risk of developing chronic non-infectious diseases (arterial hypertension, diabetes mellitus, malignant diseases), improvement mental health [4], reduced of body fat (% BF), establishment and maintenance of optimal body weight. [5, 6]

Due to continuous physical activity, the cardiovascular system undergoes a series of adaptive, physiological responses in the athlete's body, collectively called the Athletes's heart. The degree and types of changes correlate with the age and gender of the athletes, as well as the type of sport which the athlete is engaged in. [7] It implies morphological, functional and electrophysiological adaptations, which can be observed electrocardiographically during a standard sports-medical examination. It is important to recognize those physiological ECG and distinguish them from pathological findings that increase the risk of sudden cardiac death (SCD). Prevention of SCD is achieved by excluding the athlete with pathological ECG findings from the training process, considering that SCD is the leading cause of death of athletes on the field. [7, 8] In order to correctly interpret ECG findings in athletes, a standardized criteria were created in Seattle, USA in 2012, called the Seattle Criteria. This criteria were used in this study, in order to present physiological ECG findings caused by cardiac adaptation to physical activity, as well as the abnormal findings suggestive for pathological changes, that require further diagnostic evaluation. [9] The most common physiological ECG changes observed in athletes are the following: sinus bradycardia, sinus arrhythmia, ectopic atrial rhythm, first-degree AV block, second-degree AV block - Mobitz type I (Wenckebach), incomplete right branch block, isolated voltage criterion for hypertrophy, early repolarization. [9] The most common characteristic of athlete's heart is an increase in myocardial mass and enlargement of all heart cavities, primarily resulting in left ventricular hypertrophy [7], all of which is in direct proportion to extensive nutritional and oxidative demands of skeletal muscles during physical activity, in order to increase cardiac output. The cardiac output increases at the expense of stroke volume, which explains ventricular hypertrophy as a physiological adaptation. [10, 11] The most common cause of SCD in athletes is hypertrophic cardiomyopathy, [8] which implies the importance of its distinction from physiological ventricular hypertrophy, that sometimes can be a true diagnostical challenge. [12]

The aim of this study was to analyze the effect of the type of sport on the frequency of electrocardiographic changes, among two different groups of subjects, football and volleyball players, all of whom are students at the Faculty of Medicine, University of Belgrade.

Material and methods

Subjects

The study included 47 subjects, students at the Faculty of Medicine, University of Belgrade, competitors of the University League. Depending on the type of sport they are involved in, subjects were divided into two different groups. The first group consisted of 29 volleyball players, 12 of whom were males and, 17 females, aged 19 to 26 years (22.7 ± 1.8 years), who have actively been involved in sports for 3–15 years, training from 1 to 8 hours per week. The second group consisted of 18 football players, 8 of whom being males and, 10 females, 21 to 27 years old (24.5 ± 1.9 years), who have actively been training during the period from 1 to 19 years, 1 to 4.5 hours weekly. The criteria used to include the subjects in the study were being actively and competitively involved in sports as well as them being the participants of the University League. All procedures were performed in accordance with the Helsinki Declaration. The study protocol was approved by the Ethics Committee of the Faculty of Medicine, University of Belgrade. All subjects were acquainted in detail with the examination procedure and study protocol. Subjects gave signed informed consent to participate in the study.

Material and methods

All the measurements were performed in the morning hours, in the Centre for Sports Medicine and Exercise Therapy at the Institute of Medical Physiology, Faculty of Medicine, University of Belgrade, at a comfort temperature (18-22°C), atmospheric pressure of 760 mmHg and relative humidity ranging from 30 to 60%. At the beginning of the study, the following anthropometric parameters were measured in all the subjects: body height (BH) expressed in centimeters, using a standard laboratory stadiometer (Seca 214 Portable Stadiometer, Cardinal Health, Ohio, USA). Immediately afterwards, body mass (BM), expressed in kilograms, body mass index (BMI) and body fat percentage (% BF) were measured using a bioimpedance body composition analyzer (InBody 230 Body Composition Analyzer, Seoul, Korea).

The next step was performing the electrocardiographic testing at rest, in a supine position, using a twelve-lead electrocardiograph (Cardioline Delta 3 Plus Digital ECG Machine, Italy), on the standard millimeter strip speed of 25 mm/s, calibrated so that 1 mm of wave height matches to the 0.1 mV. From the obtained electrocardiograms, accordingly to the Seattle Criteria (Seattle Criteria, 2012) [9] for ECG interpretation in athletes, the following parameters were analyzed: heart rate (HR), rhythm, rhythmicity, respiratory arrhythmia, cardiac axis, duration and amplitude of individual ECG waves, segments and intervals, QTc, right atrial enlargement (RAE), left atrial enlargement (LAE), isolated voltage criteria for the left ventricular hypertrophy (LVH) and right ventricular hypertrophy (RVH), incomplete right bundle branch block (IRBBB), first degree AV block, second degree AV block - Mobitz type I (Wenckebach), and T wave inversion (TWI - T wave inversion).

Heart rate was obtained by dividing the number 1500 (the number of millimeters that the millimeter strip crosses in 60s, moving at a speed of 25 mm/s) by the number of millimeters corresponding to the distance between the two consecutive R waves (R-R interval). The rhythm was determined by the presence or absence of P waves before each QRS complex. The number of millimeters between two consecutive R waves was used to determine the rhythmicity of cardiac activity, and in order to obtain the time distance between two ventricular systoles. Respiratory (sinus) arrhythmia, as a variation of normal sinus rhythm, is observed as alternating acceleration and deceleration of cardiac activity, which corresponds to inspiration and expiration, respectively during the respiratory cycle, and was observed as an unequal R-R interval. The cardiac axis was calculated using the reference taken three-axis and six-axis coordinate systems, obtained by crossing the axes of three standard and three unipolar limb leads (the frontal plane), using the Einthoven's law, according to which the sum of voltages of QRS complex in I and III standard ECG leads is equal to the sum of the voltages of the QRS complex in the II standard ECG lead. Duration of individual ECG waves, segments and intervals was determined by multiplying the number of millimeters by 0.04s (corresponding to the value of 1mm in the horizontal scale), while the amplitude was obtained by multiplying the number of millimeters by 0.1mV (corresponding to 1mm in the vertical scale). The QTc (QT interval corrected for heart rate) was obtained by applying the Bazzett's corrective formula as the quotient of the QT interval and the square root of the RR interval, both expressed in milliseconds (ms). The amplitude of the P wave ≥ 2.5 mV in the lower ECG leads - II, III, aVF without changes in its duration, was taken as an indicator of the existence of right atrial enlargement (RAE), while the biphasic P wave in V1 lead whose final part shows a negative deflection ≥ 1 mm below the isoelectric line, with a duration of ≥ 0.04s, was taken as the criteria for left atrial enlargement (LAE). The isolated voltage criteria used for determination of LVH and RVH is the Sokolow - Lyon index. For LVH it is the sum of the amplitude of the S wave in V_1 and the R wave in $V_5 \geq 3.5$ mV, while for RVH it is the sum of the amplitude of the S wave in V_6 and the R wave in $V_1 \geq 10.5$ mV, with the cardiac axis turning to the right. The dominant diagnostic criteria for an incomplete right-branch block is the presence of an RSR' pattern in the first two precordial leads (V_1 and V_2). First-degree AV block is characterized by the prolonged PR interval ≥ 200 ms. Second degree AV block: Mobitz type I - Weckenbach was observed by progressive prolongation of each successive PR interval, until the absence of conduction of one P wave through the AV node, which is observed by the existence of P waves with the absence of QRS complex. TWI was observed in precordial leads from V_1 to V_3 and was considered as significant if the negative deflection was ≥ 1 mm.

Statistical analysis

Presented results were obtained by the methods of standard descriptive statistics, and are expressed as the arithmetic mean (X) ± standard deviation (SD) as well as the frequency of subjects with the parameter of interest. For processing anthropometric data, as well as all numerical data within the interpretation of ECG recordings, Student's T test for dependent samples was used, while for processing nominal data, the Chi square independence test was used. All the tests were used to determine the existence of a statistically significant difference in the values of observed parameters between the subjects who play football and those who play volleyball, where the value of $p<0.05$ was considered statistically significant. Statistical analyzes were performed using the Statistic package for social sciences 22 IBM U.S.A (SPSS22) program.

Results

Annex I shows the anthropometric parameters of the female subjects: BM, BH, BMI and %BF. No statistically significant difference was observed in the examined parameters between the subjects who play football and those who play volleyball.

Annex II shows the anthropometric parameters of male subjects: BM, BH, BMI and %BF. There is no observed statistically significant difference in the values of listed parameters between the subjects who play football and those who play volleyball.

Analyzed ECG parameters of all subjects are shown in Annex III. Among the subjects who play football and those who play volleyball, a statistically significant difference was observed in the values of the amplitude of the P wave in V_1 lead ($p<0.05$). P wave in the first precordial lead shows a higher values of amplitude in the subjects who play football (0.1 ± 0.04 mV) compared to those who play volleyball (0.08 ± 0.03 mV), while the values of other parameters - HR, QTc, LVH and RVH, showed no statistically significant differences between the two groups of subjects.

Annex IV shows the ECG parameters of the subjects read from the II standard ECG lead, which relate to the duration and amplitude of individual ECG waves, segments, and intervals. Among the listed parameters: P wave duration, P wave voltage, PR interval, QRS complex duration, QT interval, PQ segment, ST segment, Q wave voltage, R wave voltage, S wave voltage and QRS complex voltage, no statistically significant differences were observed between subjects who play football and those who play volleyball.

The data shown in Annex V refer to the ECG changes due to physical exercise. A statistically significant difference ($p<0.05$) was observed in the frequency of LAE in subjects playing football (10) compared to subjects playing volleyball (25), as well as in the occurrence of T wave inversion (TWI) in the first three precordial leads, which was found in 7 subjects playing football and in 4 subjects playing volleyball ($p<0.05$). No statistically significant difference was found in the frequency of IRBBB and RAE between the two groups of subjects. The analysis of ECG recordings did not show first - degree AV block, second - degree AV block - Mobitz type I (Wenckebach), nor the occurrence of respiratory arrhythmia in any of the subjects.

Discussion

The results presented in this study showed the existence of the following, physiological ECG changes among the subjects, according to the Seattle criteria: [9] sinus bradycardia, LVH, RAE, LAE, IRBBB, TWI. A statistically significant difference between the two groups of subjects, was observed only in the frequency of occurrence of LAE and TWI, as well as the amplitude of the P wave in V_1.

Karagjozova et al. [13] proved the correlation between the type of sport, according to the Mitchell's classification [14], with the frequency and degree of physiological ECG changes found in athletes. Karagjozova et al. [13] also showed that ECG changes caused by physical exercise (sinus bradycardia, first-degree AV block, early repolarization, respiratory arrhythmia, IRBBB), are occurring as a result of increased vagal tone, and represent the characteristic of sports such as football and volleyball. This finding contradicts the results of other authors [15,16], including our study. Apart from the incidence of IRBBB observed in about 50% of our subjects, the rest of these changes went unnoticed. The observed incidence of IRBBB is approximately the same as in studies of other authors (35-50%), and occurs as a consequence of right ventricular remodeling and therefore delay in the conduction of electrical impulses through the right branch of the bundle of Hiss. [16–18] The association between the influence of the type of sport and the frequency of specific ECG patterns is also demonstrated by Pelliccia et al. [19], whose study results showed the highest frequency of IRBBB in the population of football players and volleyball players, which is in accordance with our results.

Opposite to our results, two studies of Huttin and Pambo [20, 21], analized ECG findings in football players, and showed a high incidence of sinus bradycardia, first degree AV block, prolonged or shortened QTc, LVH as well as the low IRBBB frequency in these athletes. Similar to the results we presented, a high frequency of TWI in anteroseptal leads ($V_1 – V_3$) was observed, which is considered to be a pathological finding [9], and requires further diagnostic analysis and evaluation (echocardiography, cardiac MRI). According to Schnell, the occurrence of TWI is associated with high prevalence of predisposing conditions for the development of SCD (up to 45% of cases with a positive ECG findings), of which the most common is hypertrophic or arrhythmogenic cardiomyopathy. [8, 12, 22]

Although a common adaptation phenomenon, with a frequency of over 50% of athletes in studies conducted by other authors, the incidence of LVH, obtained by the isolated voltage criterion (the Sokolow-Lyon index), was low among subjects in this study. [15, 18, 23]

LAE is an extremely rare finding in the studies of the above-mentioned authors [15, 18, 23], while it is present in a total of 35 of our subjects. The Seattle criteria classifies it as an abnormal finding, and thus implies the need for further diagnostic evaluation. However, the results of studies by some authors, such as Król [24], suggest that left atrium enlargement is just another in a series of elements that make up the athlete's heart, with higher frequency in sports with lower dynamic and higher static component, which may explain the statistical difference in our study, where the occurrence of LAE is more common in subjects who play volleyball.

The limitation of this study was the absence of other diagnostic methods for the assessment of cardiac function, in addition to electrocardiography. For a full understanding of all aspects of cardiac remodeling caused by exercise, in addition to the standard twelve-lead electrocardiography (ECG), the use of imaging methods, such as echocardiography or cardiac MRI, is indicated. [7] This is important because of the possible low sensitivity and specificity of ECG findings, especially in the differential diagnosis of possible conditions that increase the risk of developing SCD, among which cardiomyopathies are the most common. [9, 12] Due to above mentioned, subjects from this study showing LAE and TWI need to undergo an additional diagnostic evaluation.

Conclusion

The results of our study showed a statistically significant difference between the two groups of subjects, in two examined parameters: LAE and TWI, while the remaining parameters, including those that represent common findings, and are conditioned by physical exercise, remained with no statistically significant difference observed. A higher incidence of LAE in subjects playing volleyball could indicate a higher degree of left atrial remodeling. More frequent occurrence of TWI in subjects playing football could be an indicative sign of a higher degree of left ventricular remodeling or a sign of hypertrophic cardiomyopathy. Based on the presented results, we can conclude that the observed changes in the ECG indicate that different types of sports can lead to changes in the electrical activity of the conduction system of the heart and heart muscle.

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ANNEX I

Chart 1. Anthropometric parameters of female subjects

	Football (n = 10)	Volleyball (n = 17)	p
Body mass (kg)	61.8 ± 7.8	67.1 ± 9.4	0.145
Body height (cm)	171 ± 5	173 ± 6	0.283
BMI	21.1 ± 2.0	22.4 ± 3.5	0.318
%BF	24.0 ± 5.1	23.7 ± 7.3	0.913

The variables are shown as X ± SD; BMI - Body Mass Index; % BF - percentage of body fat

Student’s T test for two dependent samples; * p <0.05

ANNEX II

Chart 2. Anthropometric parameters of male subjects

	Football (n = 8)	Volleyball (n = 12)	p
Body mass (kg)	79.9 ± 13.4	82.4 ± 12.3	0.668
Body height (cm)	186 ± 6	187 ± 7	0.634
BMI	23.2 ± 3.8	23.5 ± 2.5	0.863
%BF	11.5 ± 4.3	12.6 ± 4.8	0.605

The variables are shown as X ± SD; BMI - Body Mass Index; % BF - percentage of body fat

Student’s T test for two dependent samples; * p <0.05

ANNEX III

Chart 3. Electrocardiographic parameters of all subjects

	Football (n = 18)	Volleyball (n = 29)	p
HR (1/min)	70 ± 11	73 ± 9	0.300
P in V1 (mV)	0.1 ± 0.04*	0.08 ± 0.03	0.015
QTc (ms)	350 ± 29	352 ± 35	0.821
RVH (mV)	4.1 ± 2.2	3.5 ± 1.2	0.206
LVH (mV)	24.0 ± 8.1	23.6 ± 6.3	0.864

The variables are shown as X ± SD; HR - heart rate, RVH - sum of voltage of R wave in V1 and S wave in V6 lead; LVH - sum of voltages of S waves in V1 and R waves in V5 lead

Student's T test for two dependent samples; * $p < 0.05$

ANNEX IV

Chart 4. Electrocardiographic parameters of the subjects read from the II standard lead

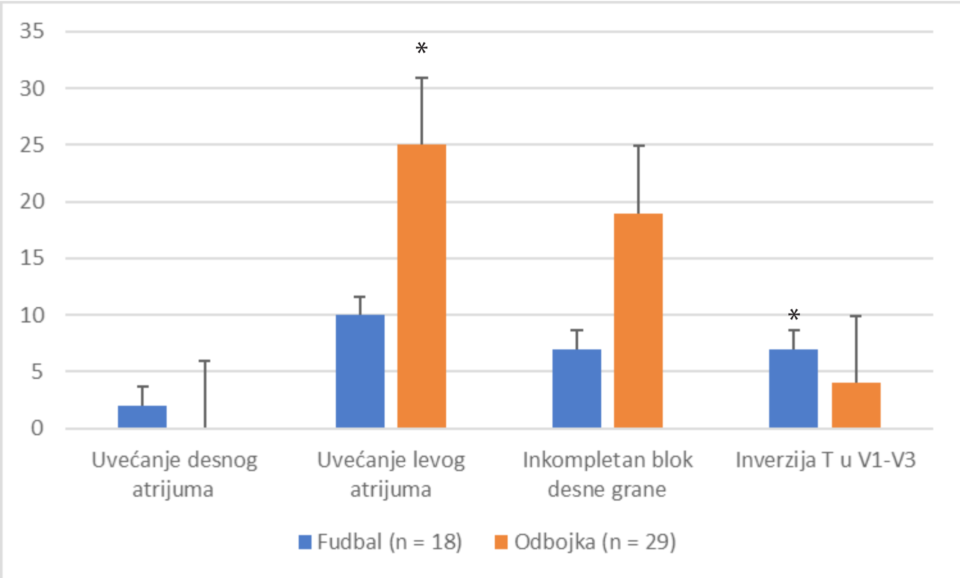
	Football (n =18)	Volleyball (n = 29)	p
P wave duration (s)	0.08 ± 0.01	0.07 ± 0.02	0.162
P wave voltage (mV)	0.14 ± 0.04	0.13 ± 0.04	0.209
PR interval (s)	0.14 ± 0.02	0.14 ± 0.02	0.865
QRS duration (s)	0.05 ± 0.02	0.05 ± 0.01	0.682
QT interval duration (s)	0.36 ± 0.03	0.35 ± 0.04	0.544
PQ segment duration (s)	0.05 ± 0.02	0.06 ± 0.02	0.341
ST segment duration (s)	0.11 ± 0.03	0.10 ± 0.03	0.183
Q wave voltage (mV)	0.69 ± 0.50	0.68 ± 0.39	0.912
R wave voltage (mV)	10.50 ± 3.95	10.29 ± 2.71	0.867
S wave voltage (mV)	1.39 ± 1.37	1.41 ± 0.82	0.984
QRS voltage (mV)	0.84 ± 0.38	0.83 ± 0.26	0.917

The variables are shown as X ± SD;

Student's T test for two dependent samples; * $p < 0.05$

ANNEX V

Graph 1. Changes in the ECG record due to physical exercise, RAE – right atrium enlargement, LAE – left atrium enlargement, IRBBB – incomplete right bundle branch block



Chi square independence test; * p <0.05