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COMPARISONS AND CORRELATIONS OF ELECTROCARDIOGRAPHIC CHANGES WITH REGARD TO CERTAIN ECHOCARDIOGRAPHIC CHARACTERISTICS IN ATHLETES

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(Original scientific paper)

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Abstract
Electrocardiography (ECG) changes, especially abnormal ones, are not in actual fact functional cardiac remodeling that occurs as a result of physical training, but rather they are most likely a reflection of a structural and/or functional cardiac disorder that can lead to SCD (Sudden Cardiac Death). To achieve the objectives of the study, two non-invasive diagnostic methods for cardiovascular evaluation were utilized:electrocardiography (ECG) and 2D transthoracic echocardiography in 54 patients with ECG changes. The comparison of left ventricle (LV) end-diastolic and end-systolic volumes indexed for the body surface area showed that the largest mean volumes, which were simultaneously above the reference values, were registered in male athletes who had an abnormal ECG, which was also confirmed by obtaining significant positive correlation between increased end-systolic volume and the presence of an abnormal ECG (r = 0.303; p = 0.026). An increased trabeculation was observed in 5 athletes, 3 of whom(10.7%) had a physiologically altered ECG, and in 1(7.1%) a borderline, whereas in another an abnormal (1/14.3%) altered ECG, with no statistically significant difference in their comparison observed (p = 0.865). These results have emphasized the need for further research in order to determine the etiology of changes, i.e. to determine the potential existence of structural cardiac disease.

Key words: *athletes, electrocardiography, echocardiography, athlete's heart*

Introduction

Regular physical activity contributes to structural, electrical and functional changes of the heart. The introduction of the ECG has opened the gates into researching the effects of sporting activities on the electrical activity of the heart, particularly the echocardiography, especially with its advanced techniques, which definitely paved the way for further understanding of the morphology and function of the athlete's heart (Eijsvogels TMH at al.,2016; Bagish AL, Wood MJ., 2011; Prior DL, La Gerche A.,2012; La Gerche A.at al.,2009; D'Andrea A, et al. ,2015; Galderisi M. et al,2015; Paterick TE. at al. 2014). Understandably, the need for examining metabolic activity and tissue characterization of the myocardium necessitated the utilization of other modalities for visualization of the heart, such as computer tomography, angiography, nuclear techniques and cardiac magnetic resonance (La Gerche A.,2012) which enabled further determination of the thin line of demarcation between the normal and the pathological in this specific population. Echocardiography at rest and under exertion due to its indisputable possibilities, especially with the application of advanced methods, availability and no less important – its low cost, continues to play a leading role in athlete's heart exams. The aim of this study is to determine the correlation of ECG changes with the investigated echocardiographic characteristics in order to promptly diagnose cardiovascular conditions that may be the cause of sudden death in athletes.

Materials and methods

A prospective cross-sectional study was conducted during 2016 and 2017, in which a total of 285 respondents (competitive athletes, recreational players) aged between 9 and 38 of both sexes (62.1% male and 37.9% female) were included. In all patients, sports anamnesis and anamnesis for the presence of certain symptoms, as well as family anamnesis for the presence of cardiovascular diseases were taken. All patients underwent a 12-channel electrocardiogram (ECG) at rest (BTL-08 MT Plus), with a paper speed of 25 mm/sec at a current voltage of 0.1 mV/mm. Subjects were in a supine position during normal quiet respiration. We divided all subjects into 4 groups according to the changes they had on their ECG, according to the international recommendations for the interpretation of electrocardiographic records (Sharma et al., 2017; Corrado et al., 2013; Drezner et al., 2013; Uberoi et al., 2011): completely normal ECG, physiologically altered ECG, borderline ECG changes and completely abnormal ECG findings. Fifty-four (54) patients underwent conventional transthoracic echocardiography by means of utilizing commercially available equipment (GE, Vivid 7). A multi-frequency transducer was used for transthoracic echocardiography. Transthoracic echocardiographic (TTE) examinations and measurements were performed by placing the patient in the left-lateral recumbent position according to the recommendations of the American Society of Echocardiography (ASE). To assess the function of the LV, we measured the following (Lang RM, et al., 2015; Quinones MA, et al.,(2002):

- End-diastolic/end-systolic LV internal dimensions measured in M-mode, expressed in mm.
- Wall thickness (septal and posterior) in systole and diastole measured in M-mode, expressed in mm.
- LV end-diastolic/end-systolic volumes expressed in ml and indexed for body surface area.

Estimation of EF (%) using the two-plane disk method (modified Simpson's rule), calculated according to the formula:

- (EDV – ESV) / (EDV × 100).

Assessment of stroke volume according to the formula:

- SV = CSA × VTI (cm) ml/удар using PW Doppler and indexed for body surface area.

Assessment of minute volume according to the formula:

- MV = SV × heart rate, liters /min, indexed for body surface area.

Mitral annular plane of systolic excursion (MAPSE) in mm with M-mode from four different points (septal, lateral, inferior and anterior) in apical four-chamber and apical two-chamber sections, and the average MAPSE was shown as the mean value of the four points.

Analyzes were performed by utilizing the SPSS statistical program, version 22.0 (IBM SPSS, Inc., Chicago, Illinois), in which for all tests conducted, a value of $p < 0.05$ was considered statistically significant. Categorical features were presented as percentages, whereas the continuous ones with mean value ± standard deviation (SD). Comparison between groups of continuous parameters was made by analysis of variance (ANOVA), and categorical parameters utilizing the Pearson Chi-square test. The relationship between the parameters and their value was examined by Pearson's and/or Spearman's correlation. To enable offline quantitative evaluation of echocardiographic data, testing was recorded on compact discs or stored in the digital memory of the echocardiographic device and then analyzed utilizing special software (EchoPAC PC 08: GE Healthcare).

Results

Considering that only 11 female athlete subjects were echocardiographically analyzed, and one each belonged to the normal and borderline ECG groups, the validity of that comparison can still be debatable. We have also presented the results according to the parameters considered in the context of gender differences. Thus, although the male athletes who had an abnormal ECG had the largest internal dimensions of the left ventricle (LV) in systole and diastole, there was still no statistically significant difference compared to the others (Table 1).

The research of the correlations showed the existence of a positive statistically significant correlation between the increased internal dimension of LV diastole and the existence of right bundle branch block (RBB) on the ECG ($r = 287$, $p = 0.036$), early repolarization ($r = 273$, $p = 0.046$) and high positive T-waves ($r = 297$, $p = 0.029$).

LV wall thickness, as well as its mass and relative wall thickness, did not differ between athletes categorized according to ECG changes, although statistically insignificantly the largest left ventricular mass, which was also above the reference level, was observed in male athlete subjects who had abnormal ECG (Table 1, Figure 1).

We have also examined the existence of ECG changes in those athletes who showed increased indexed left ventricular mass and determined that the mean Lyon-Sokolow index was 37.7 ± 10.6 mm, that is, that in 10 (58.8%) of them, there were also ECG signs of LV hypertrophy.

Table 1. Comparison of normal and differently altered ECG in relation to echocardiographic assessment of LV internal dimensions, wall thickness and volumes in systole and diastole, LV mass and systolic function in 54 athlete subjects

Echocardiographic parameters	**N (*n* = 4)**	**P (*n* = 29)**	**B (*n* = 14)**	**A (n = 7)**	**P**
LVEDd (mm)					
Male (*n* = 43)	49,7 ± 1,5	47,7 ± 4,5	50,6 ± 6,3	51,7 ± 8,6	0,332
Female (*n* = 11)	35,0	44,0 ± 4,6	46,0	44,3 ± 3,9	0,305
LVEDs (mm)					
Male (*n* = 43)	30,7 ± 1,1	29,1 ± 4,3	32,0 ± 4,6	33,0 ± 9,2	0,240
Female (*n* = 11)	20,0	26,0 ± 5,1	28,0	26,8 ± 1,3	0,493
IVSd (mm)					
Male (*n* = 43)	12,7 ± 2,1	12,3 ± 1,9	11,5 ± 1,9	12,7 ± 3,1	0,546
Female (*n* = 11)	10,0	10,0	10,0	9,25 ± 2,2	0,875
PWd (mm)					
Male (*n* = 43)	10,0 ± 3,1	11,6 ± 2,7	11,1 ± 2,9	11,5 ± 2,9	0,582
Female (*n* = 11)	8,0	8,8 ± 1,3	9,0	7,5 ± 1,3	0,502
EDV/BSA (ml/m^2)					
Male (*n* = 43)	56,7 ± 3,9	64,1 ± 10,3	69,7 ± 18,4	82,7 ± 22,4	0,090
Female (*n* = 11)	47,0	49,7 ± 8,7	59,7	53,1 ± 4,8	0,385
ESV/BSA (ml/m^2)					
Male (*n* = 43)	20,2 ± 3,4	20,2 ± 6,5	23,8 ± 7,4	33,7 ± 7,2	0,014
Female (*n* = 11)	15,3	16,5 ± 5,5	13,4	19,0 ± 1,9	0,639
LVEF (%)					
Male (*n* = 43)	64,9 ± 2,8	68,6 ± 7,5	66,0 ± 4,8	58,7 ± 7,6	0,099
Female (*n* = 11)	64,0	67,8 ± 5,4	78,0	67,0 ± 5,5	0,332
SV/BSA (ml/ m^2/stroke)	39,1 ± 13,7	48,2 ± 12,4	47,7 ± 10,7	42,7 ± 6,5	0,375
CI (L/min/m^2)	8,9 ± 4,2	9,6 ± 2,8	9,3 ± 2,5	8,5 ± 1,3	0,171
LVI mass (g/m^2)					
Male (*n* = 43)	111,3 ± 14,2	108,7 ± 20,7	107,3 ± 25,6	129,5 ± 37,7	0,509
Female (*n* = 43)	61,7	79,6 ± 9,1	79,7	76,1 ± 11,5	0,487
RWT					
Male (*n* = 43)	0,42 ± 0,1	0,47 ± 0,1	0,41 ± 0,1	0,5 ± 0,1	0,264
Female (*n* = 43)	0,46	0,41 ± 0,1	0,43	0,39 ± 0,1	0,868
MAPSE mean (mm)	15,8 ± 1,3	17,7 ± 1,9	17,6 ± 1,4	16,7 ± 2,5	0,171
MAPSV mean (cm/s)	7,6 ± 0,9	9,4 ± 1,9	9,6 ± 1,9	8,6 ± 2,2	0,233

LVEDd = left ventricular end dimension in diastole; LVEDs = left ventricular end dimension in systole; IVSd = interventricular septum in diastole; PWd = posterior wall in diastole; EDV = end diastolic volume; ESV = end systolic volume; BSA = body surface area; LVEF = left ventricular ejection fraction; SV = stroke volume; CI = cardiac index; LVI mass = left ventricular mass indexed for body surface area; RWT = relative wall thickness; MAPSE = mitral annular plane of systolic excursion; MAPSV = mitral annular plane of systolic velocity

Despite this, the research into correlations showed the absence of a significant association between ECG signs and echocardiographic confirmation of LV hypertrophy, but there was a significant association with ST-segment changes (elevation) on the ECG (r = 0.321, p = 0.018), as well as an increased Lyon-Sokolow index which was positively associated with the presence of an extended S-wave in leads V1-V3 >55 ms in the absence of a RBB finding that we classified as a borderline ECG (r = 0.204, p = 0.001).

A significant correlation with the presence of ST segment elevation on the ECG was also observed in relation to the increased thickness of the ISD (r = 0.360, p = 0.007), as well as the PW (r = 0.311, p = 0.22).

The comparison of end-diastolic and end-systolic volumes of LV indexed for body surface area showed that the largest mean volumes, which were simultaneously even above the reference values, were registered in male sports subjects who had an abnormal ECG (table 1, figure 1), which was also confirmed by obtaining a significant positive correlation between increased end-systolic volume and the existence of an abnormal ECG (r = 0.303; p = 0.026).

Athlete subjects with increased values of end-systolic volume had statistically significantly more frequent negative T-waves assessed as an abnormal ECG finding (r = 0.274, p = 0.045). Subjects with increased end-diastolic and end-systolic volumes also had a significant association with the presence of a widened S-lock in leads V1-V3 >55 ms in the absence of a RBB finding that we classified as a borderline ECG (r = 0.313, p = 0.021; r = 0.299, p = 0.028; respectively).

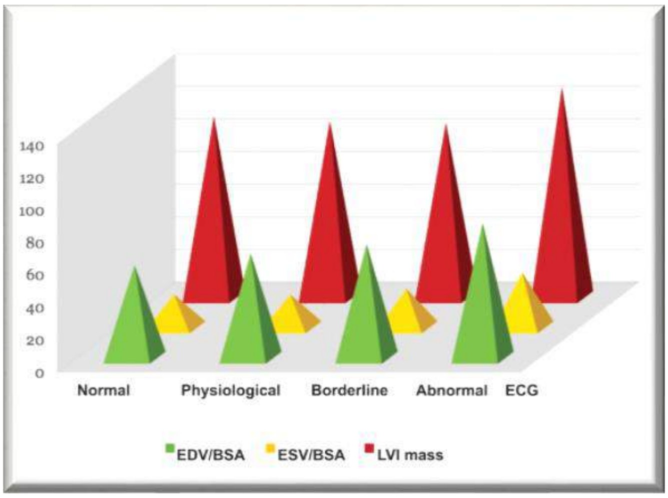

Figure 1. Graphic representation of the values of end-diastolic and end-systolic LV volume, as well as LV mass in 43 male athletes according to ECG changes.

Regarding the parameters of the systolic function, it was shown that among the athletes, although still within reference values, LVEF (Figure 2) and cardiac index (Figure 3) were statistically insignificantly lower in athletes with an abnormal ECG, while stroke volume was lower in those with a normal ECG as well, compared to others (Table 1).

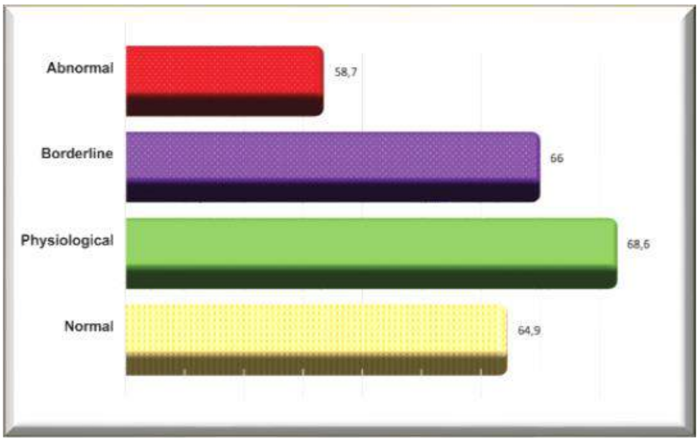

Figure 2. Graphic representation of LVEF values in 54 athlete subjects according to ECG changes

Global systolic displacement of the mitral annulus towards the left ventricular apex (MAPSE) was within reference values in all subjects, although insignificantly lower in those with normal and abnormal ECG, while the velocity of this displacement (MAPSV) was on average in all subjects lower than the reference value, but insignificantly it was most reduced in those with normal and abnormal ECG (Table 1).

The research into correlations of ECG changes and functional LV systolic parameters showed the existence of a statistically significant negative correlation between lower LVEF and the presence of depression of the ST segment (r = –356, p = 0.008), as well as the occurrence of negative T-waves in: the anterior leads V1-V4 (r = –356, p = 0.008), inferior leads D3 and aVF (r = –285, p = 0.030), as well as lateral leads D1, aVL, V5, V6 (r = -356, p = 0.008). There was a negative association between lower cardiac output and low ECG voltage with borderline statistical significance (r = –0.263, p = 0.055).

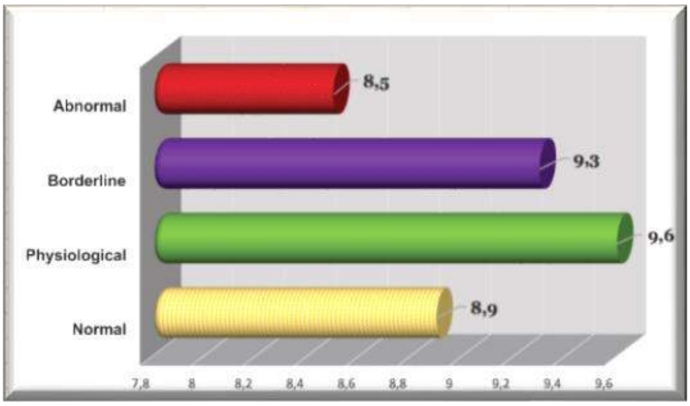

Figure 3. Graphic representation of the minute volume values (CI l/min)/m2) in 54 athlete subjects according to ECG changes

Discussion

The results of our study conducted by utilizing 2D conventional echocardiography on 54 athlete subjects, of whom 43 were male and 11 female, showed that internal diastolic dimensions greater than the upper reference limit were found in 3 male athletes (7.0%) (LVEDd = 61 mm), whereas in systole only in one male athlete, while in females the values did not deviate from the reference values.8 male and one female athlete subjects had values of end-diastolic volume greater than the upper reference limit, and in relation to end-systolic volume, 5 male and one female athlete subjects had values above the upper reference limit. There was a statistically significant difference in terms of gender, for which reason the male subjects had significantly larger internal dimensions and indexed LV volumes. This finding is also a confirmation of the impact of physical training on left ventricular dimensions and volumes, as well as for distinguishing it from pathological forms of cardiomyopathy of physical deconditioning, that is, a state of cessation of sporting activities(Galderisi M. et al,2015; Maron BJ et al.,1993; Pelliccia A. et al, 2002). Therefore, the results of studies that have been published do show a decrease in LV dimensions by 7% after cessation of sporting activities after 1-13 years, which does not occur when it is pathological cardiomyopathy in question, or the consequence of the influence of stimulants, but it is also observed that in 20% of athletes, the internal dimensions of the LV remain increased even approximately 5 years upon cessation of sports, despite the normal function of the LV and the absence of contractions (Pelliccia A. et al, 2002).

The comparison of the echocardiographic parameters in the athlete subjects with differently assessed ECG showed the absence of statistically significant differences in terms of internal dimensions and thicknesses (Table 1). Despite the absence of statistically significant differences, the athlete subjects with an abnormal ECG had the largest internal end-diastolic and end-systolic dimensions, for which reason the examination of correlations showed a statistically significant positive correlation between the increased end-diastolic LV dimension and the existence of physiological ECG changes in terms of early repolarization (r = 273, p = 0.046) and borderline normal ECG changes such as RBB (r = 287, p = 0.036) and high positive T-waves (r = 297, p = 0.029). On the other hand, the comparison of the indexed LV volumes showed that the LV end-diastolic volume with statistical borderline significance (p = 0.090) was the largest in subjects with an abnormal ECG, as was the case with the LV end-systolic volume, but with positive statistical significance (p = 0.014). LV mean volumes were at the same time above the reference values in male athletes who had an abnormal ECG (Table 1, Figure 1), which was also confirmed by obtaining a significant positive correlation between the increased end-systolic volume and the existence of an abnormal ECG (r = 0.303 ; p = 0.026). Athlete subjects with increased values of end-systolic volume had statistically significantly more frequent negative T-waves assessed as an abnormal ECG finding (r = 0.274, p = 0.045). It is already known from the literature that the presence of negative T-waves in at least two adjacent leads in athletes is a non-specific sign, but it certainly indicates an abnormality and requires additional research in order to detect potential cardiovascular diseases [Bagish AL, Wood MJ., 2011; Prior DL,La Gerche A 2012; La Gerche et al.,2009; Basavarajaiah S, et al.,2008; Maron BJ, Pelliccia A.,2006; D'Andrea A, et al.,2010; Fagard R.,2003). Subjects with increased end-diastolic and end-systolic volumes also had a significant association with the presence of an extended S-lock in leads V1-V3 > 55 ms in the absence of an RBB finding that we classified as a borderline ECG (r = 0.313, p = 0.021; r = 0.299 , p = 0.028;

consecutively). In our study, the LV end-diastolic indexed volume was significantly positively associated with the Lyon-Sokolow index (r = 0.330, p = 0.015), that is, with increased ECG voltage in addition to LVH (r = 0.257, p = 0.061).

In relation to the morphological changes of the heart, specifically the occurrence of trabeculation of the LV was found in 5 (9.3%) of the athlete subjects. The presence of trabeculae was positively associated with greater LV end-diastolic volume (r = 310; p = 0.023). In the literature, the frequency of the presence of trabeculae in athletes is similar to ours. Gati et al.,2013. in a study conducted among 1146 athletes aged between 16 and 35 (63.3% men) who participated in 27 different sports (predominantly football, rugby, cricket, tennis, swimming) and 415 controls found statistically significantly increased LV trabeculation in 18.3% of athletes compared to 7.0% of controls, and 8.1% of the athletes met the conventional echocardiographic criteria for the existence of left ventricular non-compact cardiomyopathy (LVCC) compared to none of the controls. Increased trabeculation was not related to the type of sport, nor to the intensity of the training. In addition, in contrast to LVNC, athletes with increased trabeculation had normal LV systolic (in 89%) and diastolic function (in 100%). In contrast, Caselli et al.,2016, found that among 2501 athletes marked trabeculation was found in 1.4% of them, out of which 0.4% met the criteria for LVEF based on the presence of LV dysfunction (LVEF < 50%) and/or a positive family history, that is, genetic testing.

Although the occurrence of SCD due to LVNC was not observed in the indicated studies, these athletes should be subject to additional tests (coronary stress test, stress echocardiography magnetic resonance) and long-term regular annual follow-ups.

Conclusion

These findings of ours, which are aligned with those found in the literature, merely confirm the fact that the existence of an abnormal ECG requires additional research in order to determine the etiology of the changes, i.e. determining the potential existence of a structural heart disease.

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