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COMPARISONS AND CORRELATIONS OF THE ELECTROCARDIOGRAPHY CHANGES REGARDING THE FUNCTIONAL FEATURES BEFORE, DURING AND IMMEDIATELY AFTER THE TREADMILL TEST WITH ATHLETES

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(Original scientific paper)

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Abstract

The need for cardiovascular screening in order to timely detect and diagnose the morphological and functional changes of the heart, which occur as a result of doing sport actively, and thus to avoid the occurrence of sudden cardiac death, is generally accepted. To achieve the objectives of the study, two non-invasive diagnostic methods for cardiovascular evaluation were used: electrocardiography (ECG) and the Bruce protocol test. The purpose of this study was to determine and examine the relationship of ECG changes to functional characteristics before, during, and/or immediately after exercise testing. This cross-sectional study conducted during 2016/2017 involved 285 athletes aged 9 to 38, of both sexes. They were all given a 12-channel electrocardiogram (ECG) at rest, after which personal, family and sports history and anamnesis were given, followed by a Bruce protocol test and functional parameters were examined (symptoms, metabolic equivalents, METs, test duration, exercise capacity-VO2 max, rhythm disturbance, heart rate, heart rate reserve and recovery, chronotropic incompetence (CI), systolic and diastolic blood pressure). According to ECG changes and in accordance with international recommendations for its interpretation, athletes were divided into 4 groups: with normal, physiological, borderline or abnormal ECG findings. The results showed a significant positive connection between abnormal ECG and the occurrence of rhythm disturbance during the exercise test ($r = 0.119$; $p = 0.045$); Cardiovascular capacity expressed in (METs) compared to respondents with normal ECG was significantly higher in those with physiological ECG changes ($p = 0.003$), HR reserve percentage was lowest among athletes with abnormal ECG, and CI had the highest percentage. It can be concluded that an athlete with borderline, abnormal, and possibly physiologically assessed ECG should undergo further evaluation.

Keywords: *athletes, electrocardiogram, exercise test, functional features*

Introduction

Physical exercise/training and long physical activity leads to a morphological and functional remodelling of the heart, i.e. a "sports heart". (Eijsvogels et al., 2014) In addition, electrical changes occur which are manifested by changes in the electrocardiogram (ECG). It is of great importance to distinguish these typically training-related changes from the pathological changes that imply the presence of mechanical or electrical malformations leading to an increased risk of sudden cardiac death (SCD) (Corrado et al., 2009; Papadakis and Sharma, 2009; Harmon et al.2015), and to prevent unnecessary examinations in athletes and their possible removal from a competitive sport. The latest international consensual standard for electrocardiogram interpretation in athletes from 2017 (Sharma et al.,2017) is just another contribution to a more accurate differentiation of physiological and pathological changes in athletes. Therefore, based on these recommendations, athletes with positive family history of heart disease or premature SCD, relevant symptoms, abnormal physical examination or ECG abnormalities which are not related to physical training, need additional tests before consent is given for further practice of competitive sport (Corrado et al., 2013). Doing exercise testing in case of indications like the above mentioned, can give us not only data on hidden illnesses and possible risk for doing sports, but also on physical performance data, training level, maximum oxygen consumption, heart frequency rate reserve percentage, systolic and diastolic blood pressure changes, rhythm disturbance (Mora et al.,2003). This study was performed in order to determine and examine the relation of ECG changes with functional features before, during, and/or immediately after the exercise test.

Material and methods.

This prospective cross-sectional study conducted during 2016/2017, included 285 respondents (competitive athletes, recreational athletes) aged 9 to 38, of both sexes (62.1% men and 37.9% women). All patients were given sports anamnesis and anamnesis of certain symptoms, as well as family history for the presence of cardiovascular diseases. They were all given a 12-channel stationary electrocardiogram (ECG) and an exercise test on the treadmill, following the Bruce protocol. The examination was performed at least 12 hours after the last physical activity of the respondents, with a 12-channel ECG (BTL-08 MT Plus), with a paper movement speed of 25 mm / sec at a voltage of 0.1 mV / mm. Respondents were in a supine position with normal restful breathing. We divided all participants into 4 groups according to the changes they had on the ECG, in accordance with the international recommendations for interpretation of the ECG record (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 finding.

The exercise test was performed on all respondents over 9 years of age who were capable, willing and had no contraindications to exercising, immediately after electrocardiography. Testing was performed using a progressively growing ergometric-step test on the treadmill (ergo_run medical_α 24) following the Bruce protocol, consisting of 6 degrees of exercises with 3 minutes duration. All respondents were encouraged to reach their maximum exercise capacity which would not cause symptoms and/or worsen cardiovascular status.

Features related to the exercise testing

Present symptoms, n (/%)
Type of symptoms, n (%)
- Tiredness
- Chest pain
- Legs pain
METs
Test duration (min)
Exercise capacity (%)
Exercise capacity
< 100%, n (%)
≥ 100%, n (%)
Calculated $VO_{2\,max}$ (ml/kg)/min
Base HR (beats/min)
HR Maximum (beats/min)
HR change (beats/min)
% HRR
CI according to % HRR, n (%)
Recovery reserve of HR
Recovery reserve of HR
≤ 18 n (%)
> 18 n (%)
BPs base (mmHg)
BPs maximum(mmHg)
BPs (mmHg)
BPd base (mmHg)
BPd maximum (mmHg)
BPd change (mmHg)
Rhythm disturbance, n (%)

METs = metabolic equivalents to the amount of oxygen consumption (in standby= 3.5 kg O2/min; HR = heart rate; BPs = systolic blood pressure; BPd = diastolic blood pressure; VPC = ventricular premature contraction; %HRR = percentage of heart rate reserve; CI = chronotropic incompetence

Analyzes were conducted using statistics software SPSS version 22.0 (IBM SPSS, Inc., Chicago, Illinois), and for all tests, the p value <0.05 was considered statistically significant. The categorical features were represented in percentages, and the continuous ones with median value ± standard deviation (SD). The comparison between the groups of continuous parameters was done by analysing the variation (ANOVA), whereas between the category parameters with Pearson Chi-square testing. The relationship between the parameters and their values was examined with Pearson and/or Spearman correlation.

Results

Out of 285 respondents - athletes (Figure 1), 54(18.9%) had absolutely normal ECG, 148 (51.9%) of the respondents had physiological training-related ECG changes, 61(21.4%) had borderline ECG changes, 22 had absolutely abnormal ECG findings (7.7%)

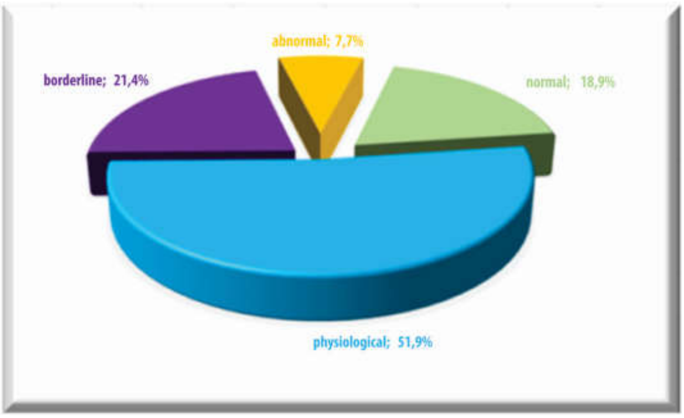

Figure 1. Incidence of ECG changes according to International recommendations for electrocardiographic interpretation in athletes (5)

The comparison of the results of the exercise test with athletes interviewed, and based on the ECG changes (Chart 1), shows that during the exercise, the symptoms occurred in almost identical percentage in the four groups of athletes (p = 0.965). The cardiovascular capacity manifested by the achieved METs was significantly higher in those with physiological ECG changes compared to those with normal ECG changes (p = 0.003), as was the case regarding the test duration (in minutes), which was significantly longer with the same group of respondents (p = 0.009). The achieved exercise capacity was insignificantly highest in athletes with abnormal ECG, i.e. the lowest in those with normal ECG (p = 0.230). The calculated maximum aerobic capacity (VO2max) was statistically and significantly higher among athletes with physiological and abnormal ECG.

Chart 1 *Comparison of normal and differently changed ECG regarding the features related to the exercise testing in 285 athletes*

Functional features	**N (*n* = 54)**	**F (*n* = 148)**	**B (*n* = 61)**	**A (*n* = 22)**	**P**
Symptoms present, *n* (/%)	6/11,1	14/9,5	7/11,5	2/9,1	0,965
METs	12,1 ± 3,4	14,1 ± 3,1	13,5 ± 3,5	13,5 ± 3,3	0,003
Test duration (min)	10,0 ± 3,1	11,6 ± 2,7	11,1 ± 2,9	11,5 ± 2,9	0,009
Exercise capacity (%)	94,8 ± 21,4	99,6 ± 16,1	96,7 ± 15,0	101,3 ± 18,1	0,230
Calculated $VO_{2\,max}$ (ml/kg/min)	36,5 ± 8,8	41,8 ± 8,1	40,2 ± 8,5	41,9 ± 7,9	0,001
Rhythm disruption, *n* (/%)	0	1/0,7	2/3,3	1/4,5	0,216

N=normal; F = physiologically changed; B = borderline; A = abnormal. METs = metabolic equivalents to the amount of oxygen consumption, at standby= 3.5 O_2/kg/min; VO_{2max} = aerobic capacity

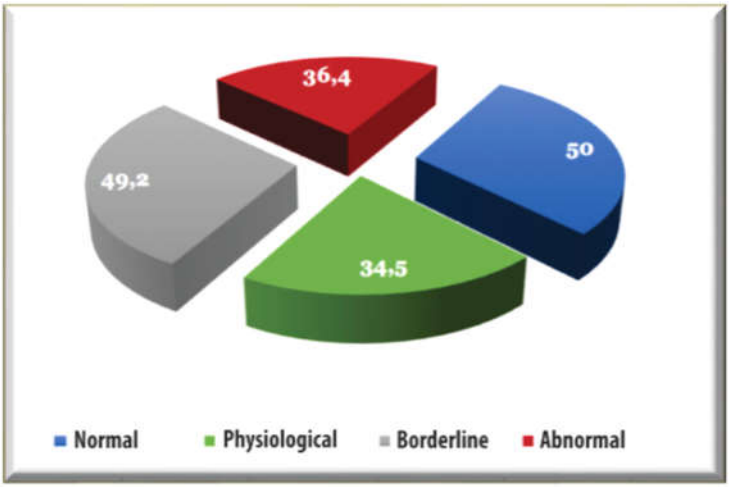

Figure 2. Presence of cardiovascular capacity in percentages < 100% in athletes, based on the ECG changes

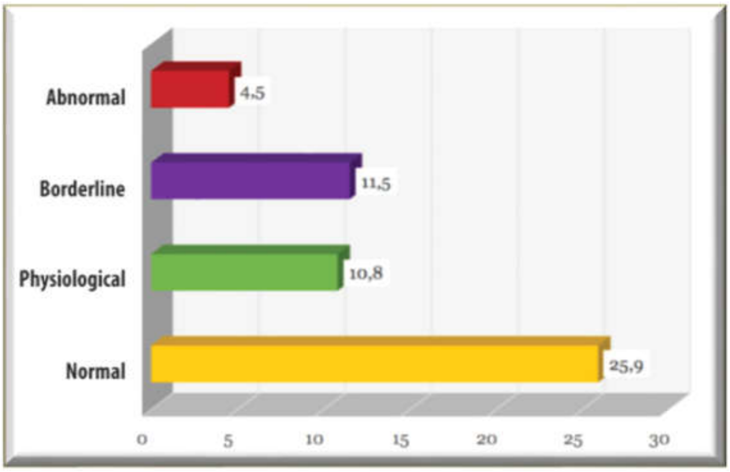

Figure 3. Percentage of the maximum aerobic capacity representation in athletes based on the ECG changes.

When comparing ECG changes and achieved exercise capacity divided by ≥100% and <100%, the analysis showed that athletes with physiological changes 51 (34.5%) or abnormal ECG 8 (36.4%) with statistical borderline significance (p = 0.092) had a lower percentage of achieved capacity <100% compared to those with normal and borderline ECGs (Figure 2)

In terms of maximum aerobic capacity (VO2max), the comparison of ECG changes and aerobic capacity divided by ≥30 ml / kg / min and <30 ml showed that statistically significant (p = 0.020) percentages of athletes with normal ECG percentages 14 (25.9%), had lower aerobic capacity during the exercise test compared to the others (Figure 3).

Heart rate abnormalities in the form of premature ventricular contractions appear not to be significant in percentage, most commonly in athletes with abnormal ECG (Chart 1). Correlation analysis showed that there was a significant positive connection between abnormal ECG and rhythm disturbance during the exercise test. (r = 0,119; p = 0,045).

Comparison of resting heart rate (HR) values, peak of the exercise and its changes did not show significant differences between the groups of athletes examined, although its values were highest among respondents with abnormal ECG (Chart 2). Although the HR reserve percentage (% HRR) was the lowest among respondents with abnormal ECG, as was the highest percentage of chronic incompetence (CI) defined as the HR reserve percentage (% HRR) of ≤85%. However, the difference did not show statistical significance, and no significant correlation was obtained between them.

The abnormal reserve of heart rate recovery one minute after the test interruption of 18 beats/ minute, showed no significant differences among the athletes interviewed, divided by ECG changes.

The change in blood pressure (systolic/diastolic) was within the normal exercise response and there was no significant difference in the comparison of athletes interviewed according to the ECG changes.

Chart 2 Comparison of normal and differently changed ECG regarding the heart rate and blood pressure during the exercise test in 285 athletes examined

Functional features	**N (*n* = 54)**	**P (*n* = 148)**	**B (*n* = 61)**	**A (*n* = 22)**	**P**
Base HR (beats/min)	87,4 ± 16,1	83,3 ± 15,3	85,7 ± 17,5	81,5 ± 16,8	0,313
Maximum HR (beats/min)	169,4 ± 5,9	169,2 ± 7,9	168,5 ± 10,4	167,2 ± 7,2	0,688
HR change (beats/min)	81,3 ± 15,9	85,8 ± 15,9	83,3 ± 18,8	88,2 ± 22,9	0,254
%HRR	84,3 ± 3,6	84,5 ± 4,3	83,8 ± 5,2	83,3 ± 4,0	0,514
CI according to % HRR, n (%)	36 (66,7%)	82 (55,4%)	40 (65,6%)	17 (77,3%)	0,129
HR recovery base	36,5 ± 12,5	35,9 ± 12,2	37,4 ± 12,8	36,7 ± 8,1	0,860
HR recovery base ≤ 18, *n* (%)	3/5,6	8/5,4	2/3,3	0	0,649
BPs base (mmHg)	116,3 ± 8,8	117,9 ± 10,3	117,5 ± 9,3	118,8 ± 7,6	0,686
BPs maximal (mmHg)	147,3 ± 12,5	150,6 ± 14,3	150,3 ± 13,4	149,0 ± 15,8	0,504
BPs change (mmHg)	31,1 ± 12,5	32,8 ± 13,6	32,8 ± 11,9	29,8 ± 13,3	0,663
BPd base (mmHg)	77,7 ± 6,1	76,9 ± 7,1	75,7 ± 6,1	77,9 ± 4,1	0,349
BPd maximal (mmHg)	80,1 ± 6,4	80,1 ± 6,9	79,8 ± 5,5	80,5 ± 4,7	0,813
BPd change (mmHg)	2,3 ± 4,1	3,9 ± 6,8	4,1 ± 5,7	2,4 ± 6,0	0,259

N=normal; F = physiologically changed; B = borderline; A = abnormal. HR = heart rate, %HRR = percentage of heart rate reserve, CI= chronotropic incompetence; BPs=systolic blood pressure; BPd=diastolic blood pressure

Discussion

The exercise test is a non-invasive method that can determine the level of physical fitness, maximal oxygen uptake, percentage of heart rate reserve, changes in systolic and diastolic blood pressure, rhythm disturbances, and detect coronary artery disease. (CAD) (Arena and Guazzi, 2008; Pigozziet al., 2005; Spin et al., 2002; Gibbons et al., 2000). The Bruce protocol exercise test is a standard procedure used to test athletes, but is a rarely effective test for top athletes preparing for world-class competitions, i.e. determining specific hemodynamic and metabolic needs (Sarma and Levine, 2016). This method of testing is particularly useful in symptomatic patients who are moderately likely to have cardiovascular disorder and to assess the probability and degree of coronary disease.

When comparing the results of the exercise test in athletes, divided by ECG changes, it was shown (Chart 1) that the cardiovascular capacity manifested by the achieved METs was significantly higher in the respondents with physiological ECG changes ($p = 0.003$) as opposed to the athletes with normal ECG, as was the case regarding the test duration that was significantly longer in the same group of respondents ($p = 0.009$). The peak exercise capacity was not significantly higher in athletes with abnormal ECG, i.e. the lowest in those with normal ECG ($p = 0.230$). The calculated maximal aerobic capacity (VO2max) was statistically and significantly higher in physiological and abnormal ECG athletes.

In terms of maximal aerobic capacity (VO2max), the comparison of ECG changes and aerobic capacity divided by ≥30 ml/kg/min and <30 ml showed that athletes with normal ECG 14 (25.9%), are with statistically significant percentage ($p = 0.020$), compared to those who had lower aerobic capacity during exercising (Figure 3). Significant positive connection was found between the abnormal ECG and rhythm disturbance during the exercising.

Such results of our study are consistent with those from the literature. A number of studies have shown that the maximum amount of effort, if it is from 8 to 10 METs (approximately 25 to 35 VO2max (ml/min)/kg), is associated with less cardiovascular diseases in men and women whose predictive value exceeds all information obtained from ECG changes during testing (Mora et al., 2003; Mayers et al.2002). Even in adults with moderate or high risk of coronary artery disease, the possibility of myocardial ischemia is uncommon in those who have reached an exercise capacity of> 10 METs. On the other hand, Bourque et al. (Bourgue et al., 2009) in 2009 reported the results of exercise tests of 974 respondents, out of which 473 had METs-10s ≥ 10. Of this subgroup, only two (0.4%) showed ischemia), whereas respondents who achieved METs ≤ 7 reported as much as 18 times the value of myocardial ischemia.

Conclusion

Functional characteristics assessed by the exercise test showed that test respondents – athletes with normal ECG had statistically significantly less METs, less test duration (in minutes), and less exercise capacity and oxygen consumption.

An athlete with limited, abnormal, and possible physiologically assessed ECG should undergo further evaluation, but the findings of absence of cardiovascular disease should not exclude the close annual follow-up of these athletes, especially their ECG.

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