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Frequency of Electrocardiographic Changes in Trained Athletes in the Republic of Macedonia

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Abstract

BACKGROUND: The use of a 12-lead electrocardiogram (ECG) in the screening of young athletes still has some controversies regarding the cost-benefit of the procedure.

AIM: We wanted to identify types and frequency of ECG changes in athletes in the Republic of Macedonia as well as its relation to age, gender, duration, frequency and type of sports.

METHODS: The study population included 256 trained amateur athletes who were prospectively examined.

RESULTS: The 12-lead ECG patterns were considered normal in 19.9% of athletes, with common training-related changes found in 48.8%, while abnormal and borderline ECG changes were present in 6.6% and 24.6% of athletes respectively. ECG changes were more frequent in males than in females without significant difference regarding the age of athletes. There was a significant correlation between more pronounced ECG changes and longer duration of sports engagement, higher duration of sports activity and type of sport practised.

CONCLUSION: The prevalence of abnormal ECG patterns in athletes in RM which could indicate structural cardiac disease and greater risk of sudden cardiac death exist in a proportion that should implicate mandatory 12-lead ECG in the pre-participation screening program and further on the regular annual basis.

Introduction

In the context of increased awareness of the positive effects of sports in the prevention of cardiovascular morbidity and mortality, a large proportion of the young population participates in competitive or recreational sports activity. Unfortunately, a variety of cardiovascular diseases also represent the most common cause of sudden death (SCD) during sports and/or exercise in athletes < 35 years of age [1-4].

Despite some limitation regarding its sensitivity and specificity, the 12-lead electrocardiogram (ECG) was established as an essential tool in the evaluation of athletes that may enable detection of cardiovascular abnormalities especially associated with increased risk of sudden cardiac death (SCD) during sports [5-12]. However, ECG changes in athletes are common and usually, reflect an adaptation of the heart to regular physical training (physiological changes or training-related abnormalities) that should be distinguished from uncommon and training-unrelated ECG changes which represent the pathological state of the heart and enhance the cardiovascular risk [10-12].

Identification of ECG abnormalities among athletes and their correct interpretation has a potential positive effect on the athlete's cardiovascular management, prevents unnecessary distress and produces cost savings. Hence, we conducted the current study to examine the prevalence of ECG abnormalities among young athletes in the Republic of Macedonia as well as to assess its possible associations with physical training.

Methods

The study population included 256 young athletes of both genders, who were prospectively examined in the Sports clinic of the Institute of Physiology, Medical School, Skopje from October 2016 to June 2017. The largest proportion comprised amateur athletes engaged predominantly in soccer (25.8%), basketball (12.1%), handball (29.7%), volleyball (10.2%), tennis (6.3%) and to a lesser extent, martial arts (2.7%), cycling (0.8%), and swimming, boxing, skiing, triathlon and gymnastics (0.4% each). Twenty-five individuals (9.8%) were engaged in recreational sport and fitness on a regular basis. However, we classified sports by their relative static and dynamic components as well by the level of intensity (low, medium, high) based on Mitchell's classification [13], but adapted it according to the type of sport that is mostly practised in our country.

Electrocardiography

Standard 12-lead ECGs were performed with the subject in a supine position during quiet respiration and recorded at 25 mm/s. Electrocardiography was performed using standard 12-lead positions using an equipment of BTL Industries Ltd, UK. ECG tracings were obtained at least 12 h following the last athletic activity. ECG patterns were evaluated according to the international recommended criteria by cardiologist [11-16]. Common training-related criteria were as follows: sinus bradycardia or sinus arrhythmia, ectopic atrial or junctional rhythm, increased QRS amplitude meeting criteria for left or right ventricular hypertrophy (LVH or RVH) taking into account Lyon- Sokolow index (S wave in V1 +R wave in V5 or V6 ≥35 mm), incomplete right bundle branch block (RBBB) (QRS duration <120 ms), early repolarization/ST-segment elevation, prolonged PR interval, Mobitz type 1 atrioventricular (AV) block, and T-wave inversion V1-V3 in < 16 years old.

Borderline ECG changes were considered if left or right axis deviation and left or right enlargement as well complete RBBB were present. The following criteria were considered as evidence of abnormal ECG: T wave inversion, ST-segment depression, pathologic Q waves (> 4 mm deep in any lead except III and aVR), complete LBBB, QRS ≥ 140 ms duration, epsilon wave, ventricular pre-excitation, prolonged QT interval, Brugada Type I pattern, profound sinus bradycardia < 30 bpm, PR interval ≥ 400 ms, Mobitz type II second-degree AV block, third-degree AV block, ≥ 2 premature ventricular contractions (PVC), atrial tachyarrhythmia, ventricular arrhythmias. However, we identified more ECG abnormalities that were not classified [11] but mentioned as potential pathological variants in favour of underlying cardiomyopathies (CMP) [13-15]. Therefore, abnormalities like low voltage in limb leads, poor precordial R wave progression, delayed S wave upstroke of > 55 ms in leads V1–V3 and high positive T waves (> 15 mm) we further classified as borderline ECG changes.

Statistical analysis

Categorical parameters were summarised as percentages and continuous parameters as mean ±SD. Comparisons among groups were performed using analysis of variance (ANOVA) for continuous parameters and Pearson's chi-square test for categorical parameters. Assessment of correlation was done using Pearson's correlation analysis. All data analysis was performed using SPSS version 22.0 (IBM SPSS, Inc., Chicago, Illinois) and a p-value ≤ 0.05 was considered significant.

Results

Out of 256 athletes included in our study, 150/58.6% were males, and 106/41.4% were females. Athletes were aged 19.3 ± 5.7 years (range 9-38 years), the height was 174.0±13.8 cm (range 130-211 cm), weight 69.2 ± 16.7 kg (range 26-120 kg). Included athletes were almost identically distributed among ages (71/27.7% in the range of 9-16 years, 103/40.2% in the range of 16-21 years and 82/32.0% in athletes over 21 years), while athletes ≥35 years were only 1.2% (3 individuals) of the study population. According to Mitchell's classification of sports [13], a large percentage of athletes included in our study were represented by a low dynamic low static and low dynamic medium static component of the sport (Table 1). The average time spent in sports activities was 11.6 ± 8.5 h (1-6 h in 31.6% and > 6 h in 68.4%) per week or 2.1 ± 1.9 h per day.

Table 1: Adapted classification of sports according to static and dynamic component and frequency of each sport in our study [13]

		Dynamic component		
Static component		*Low*	*Medium*	*High*
	High	**10/3.9%** Martial arts Weightlifting Gymnastics	**25/9.5%** Skiing Bodybuilding	**5/2.0%** Boxing Kayaking Cycling Triathlon
	Medium	Motorcycling	Running (sprint)	**124/48.4%** Basketball Running (middle distance) Swimming Team handball
	Low	Billiards Bowling	**26/10.2%** Volleyball	**66/25.8%** Race walking Running (long distance) Soccer Tennis

Electrocardiography

The ECG was considered normal in 51/19.9% of athletes, with common training-related (physiological) changes found in 125/48.8% of athletes (Figure 1). The most frequent physiological abnormalities with almost identical percentage were increased QRS amplitude in favour of LVH (108/42.2%) and ST-segment elevation (102/39.8%) (Table 2).

Table 2: Frequency of common ECG training-related changes in 256 athletes undergoing cardiovascular screening

ECG training-related changes	Athletes n (%)
Sinus bradycardia	64 (25.0)
Respiratory arrhythmia	11 (4.3)
Incomplete RBBB	78 (30.5)
Prolonged PR interval (first degree AV block)	6 (2.3)
Increased QRS amplitude in favour of LVH	108 (42.2)
Early repolarization	45 (17.6)
ST- segment elevation	102 (39.8)
T-wave inversion in V1-V3 in < 16 years old	6 (2.3)

AV=atrioventricular; LVH=left ventricular hypertrophy; RBBB=right bundle branch block.

As for abnormal and borderline ECG changes that were present in 17/6.6% and 63/24.6% athletes, respectively (Figure 1), distinctly abnormal patterns represented as diffusely inverted T-waves in precordial and/or standard leads was most frequently found in 19/7.4% of athletes along with borderline changes represented as poor precordial R wave progression (71/27.7%) and delayed S wave upstroke of > 55 ms in leads V1–V3 (37/14.5%) (Table 3).

Table 3: Frequency of borderline, abnormal and some additional changes in 256 athletes undergoing cardiovascular screening

Borderline and/or abnormal ECG changes	Athletes n (%)
Low voltage in limb leads	4 (1.6)
Right axis deviation	1 (0.4)
RBBB	15 (5.9)
Pathologic Q waves	1 (0.4)
Poor precordial R wave progression	71 (27.7)
Delayed S wave upstroke of > 55ms in leads V1–V3	37 (14.5)
ST-segment depression	3 (1.2)
Negative T wave	16 (6.3)
Anterior	11 (4.3)
Inferior	4 (1.6)
Lateral	1 (0.4)

AV=atrioventricular; RBBB=right bundle branch block.

Comparison and correlations of ECG changes

Age was almost identical among athletes with physiological, borderline and/or abnormal ECG changes while those with normal ECG were insignificantly younger (Table 4). There was a lack of significant correlation between age and presence of any ECG changes. As for the gender, ECG changes were more frequent in males than in females (p = 0.0001) (Table 4) with a significant correlation between male gender and ECG changes, especially ECG abnormalities (r = -0.270; p = 0.0001). Athletes that were longer engaged in sports activities showed more frequent presence of ECG borderline changes and/or abnormality (p = 0.086, Table 4), which was confirmed by a significant correlation between more pronounced ECG changes and longer duration of sports engagement (r = 0.153; p = 0.015).

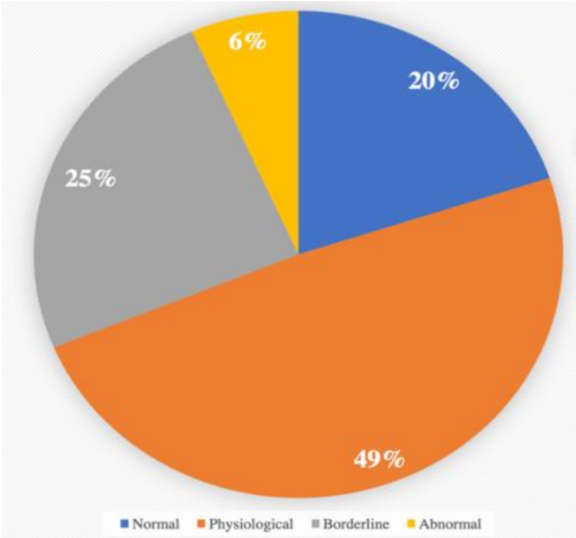

Figure 1: Frequency of ECG changes in 256 athletes

Also, athletes with higher duration of sports activity on daily and/or weekly basis (Table 4) had more frequent ECG abnormalities (p = 0.066, p = 0.003, respectively). In addition there was a significant correlation between ECG abnormalities and higher duration of sport activity on daily and weekly basis (r = 0.158; p = 0.012; r = 0.185; p = 0.003; respectively). When we compared the type of ECG abnormalities and duration of weekly sports activity divided into three categories (1-6 h; 7-14h; ≥15h), the analysis showed that only complete RBBB was significantly present in athletes with the highest duration of sports activity (p = 0.002). Furthermore, regarding Mitchell's [13] classification of sports, common training-related (physiological) as well as borderline and abnormal ECG changes were almost identically most frequently present in athletes engaged in high dynamic, low static and especially in high dynamic, moderate static sports (Table 4). Abnormal ECG in contrast with other ECG changes was significantly more frequently present in low dynamic, high static sports (p = 0.031).

Finally, about the type of sports discipline, individuals engaged in soccer, basketball, volleyball and handball showed a larger proportion of physiological and borderline ECG changes, although without a significant difference (Table 4). More pronounced ECG changes were significantly related to the type of sport practised (r = -0.137, p = 0.028) as follows: soccer, basketball, volleyball, handball, tennis and martial arts. In this respect it is important to emphasize that these sports were also significantly correlated with greater number of years of athletes' sport engagement (r = -0.335, p = 0.0001), higher duration of sport activity on weekly basis (r = -0.224, p = 0.0001) as well as higher amount of weight lifting (r = -0.165, p = 0.009).

Table 4: Comparison of normal ECG and different types of ECG changes about age, gender, types and duration of sport of 256 athletes

	N n = 51	Ph N = 125	B N = 63	A N = 17	p
Age (years)	18.8 ± 6.2	19.5 ± 5.6	19.3 ± 5.6	19.2 ± 6.5	0.890
Age ranges (n/%)					
9-15 years (n/%)	17/23.9	31/43.7	18/25.4	5/7.0	
16-21 years (n/%)	21/20.4	50/48.5	25/24.3	7/6.8	0.907
> 21 years (n/%)	13/15.9	44/53.7	20/24.4	5/6.1	
Gender (n/%)					
Male	12/8.0	83/55.3	43/28.7	12/8.0	0.0001
Female	39/36.8	42/39.6	20/18.9	5/4.7	
Duration of sport engagement (years)	7.4 ± 3.9	8.8 ± 4.1	9.3 ± 4.9	9.9 ± 4.8	0.086
Sport activity daily (h)	1.6 ± 0.8	1.9 ± 1.2	2.5 ± 3.2	2.5 ± 1.4	0.066
Sport activity weekly (h)	9.3 ± 7.3	11.3 ± 8.2	12.8 ± 8.3	15.6 ± 12.1	0.030
Type of sport activity* (n/%)					
Low dynamic, high static	1/2.0	4/3.2	2/3.2	3/17.6	
Moderate dynamic, low static	7/13.7	11/8.8	8/12.7	0	
Moderate dynamic, high static	10/19.6	12/9.6	3/4.8	0	0.031
High dynamic, low static	7/13.7	37/29.6	17/27.0	5/29.4	
High dynamic, moderate static	26/51.0	57/45.6	32/50.8	9/52.9	
High dynamic, high static	0	4/3.2	1/1.6	0	
Type of sports activity (n/%)					
Soccer	7/10.6	37/56.1	17/25.8	5/7.6	
Basketball	0	17/54.8	11/35.5	3/9.7	
Handball	23/30.3	32/42.1	16/21.1	5/6.6	0.255
Volleyball	7/26.9	11/42.3	8/30.8	0	
Tennis	3/18.8	7/43.8	5/31.3	1/6.3	
Martial sports	1/14.3	2/28.6	2/28.6	2/28.6	

A = abnormal; B = borderline; N = normal; Ph = physiological changes. * According to Mitchell's classification [13].

Discussion

Taking into account the recommendation of interpretation of ECG issued by Sharma et al. [11], common training-related (physiological) ECG changes were found in 125/48.8% of 256 investigated young trained athletes in RM, most frequently represented by increased QRS amplitude in favor of LVH (108/42.2%), ST-segment elevation (102/39.8%), incomplete RBBB (78/30.5%), sinus bradycardia (64/25.0%) and early repolarization (45/17.6%).

According to numerous studies isolated increased QRS amplitude meeting ECG voltage criteria for LVH, which is a result of cardiac conditioning associated with cardiac morphological changes, is a common finding and present in up to 50% among athletes if Sokolow-Lyon criteria were used [14-16, 18, 19]. However, evaluation of athletes with isolated increased QRS voltage using imaging techniques (echocardiography and/or cardiac MRI) showed a low percentage (<2%) of hypertrophic cardiomyopathy (HCM) which implicated no need for further evaluation [11, 18]. As most of the authors have observed, the prevalence of incomplete RBBB as a result of remodelling of an athlete's right ventricle which leads to conduction delay has been estimated to range from 35% to 50% [5, 10, 11, 14-16, 18] which is by our results. The frequency of early repolarization, sinus bradycardia and/or prolonged PR interval as a training-related augmentation of vagal tone found in our study are in line with published percentages [10, 11, 14/16, 18].

According to Mitchell's (13) classification of sports, common training-related (physiological) ECG changes in our study were most frequently present in athletes engaged in high dynamic, low static and especially in high dynamic, moderate static sports represented mostly by soccer, basketball and handball which generally differ from the results of other studies where participation in sports that require high endurance, such as cycling, cross-country skiing, and rowing/canoeing has been shown to be significantly associated with a higher rate and greater extent of physiological ECG changes [10, 18]. This difference might be due to a very low percentage of athletes engaged in latter sports in our country, hence in our study, too.

Borderline ECG changes [11] were present in 24.6% of athletes, being in a larger percentage than in other studies [13-15] because we included more ECG changes that have a potential role as represents in development of CMP. Complete RBBB was detected in 5.9% of athletes, which was more frequent than prevalence showed in other studies that ranged from 0.5% to 2.5% [5, 11, 20]. This might be a result of a more pronounced cardiac remodelling of an athlete's right ventricle which leads to conduction delay [5, 11, 16, 20], especially having in mind that in our study complete RBBB was significantly present in athletes with the weekly highest duration of sports activity. Unfortunately, we could not confirm the existence of rare, but possible structural cardiac disease without using imaging techniques (echocardiography, cardiac magnetic resonance), which means that further evaluation would be justified. However, it could also represent an idiopathic, isolated and clinically benign conduction interruption/ delay through the right bundle branch. ECG changes like delayed S wave upstroke of > 55 ms in leads V1–V3 in the absence of RBBB was found in 14.5% of athletes in our study, and Drezner et al. [16] have indicated that it is present in up to 95% of patients with arrhythmogenic right ventricular cardiomyopathy (ARVC) and is a frequent finding in those with mild QRS prolongation, which was also confirmed in our study with a significant correlation between QRS duration and presence of this ECG change (r=0.196, p=0.002). Although it represents a minor diagnostic criterion for ARVC [21], further cardiac evaluation in athletes with such ECG changes seems wise. Another frequent ECG change was the poor precordial R wave progression (PRWP) that was found in a considerable percentage (27.7%) among athletes in our study. This is not surprising having in mind that it could result from the clockwise rotation caused by right ventricular enlargement and/or implicated LV hypertrophy, which are not rare conditions in athletes, as well as ARVC [16, 21, 22] which emphasizes the need for further evaluation. Both borderline ECG changes were not related to the weekly duration of sports activity, but the delayed S wave upstroke was significantly related to sports like soccer and basketball (r = -0.144, p = 0.021).

Distinctly abnormal ECG changes were present in 6.6% of athletes, represented mostly (6.3%) as diffusely inverted T-waves (TWI) in precordial and/or standard leads that appeared as isolated ECG change and in 3 athletes they were associated with ST-segment depression. We found TWI in V1-V3 leads that appeared in athletes aged < 16 years as a juvenile physiological ECG change in 1.2% of athletes, which was consistent with other studies [5, 11, 16, 23]. However, TWI in athletes aged ≥16 years appeared in a substantial percentage in our study that was in line with most published data [5, 10, 11, 16, 23]. Given that Schnell et al. [24] speculate that TWI should be considered pathological until proven otherwise regarding the fact that it was associated with cardiac pathology in 45% of athletes, the appearance of TWI in athletes need further evaluation for underlying structural heart disease. Furthermore, it is well known that TWI in the inferior or lateral leads is common in hypertrophic cardiomyopathy, but should also raise a suspicion of ischemic heart disease, aortic valve disease, non-compaction cardiomyopathy, whereas TWI in the right precordial leads or beyond in the absence of a complete RBBB is a common finding in ARVC, especially when such findings are associated with ST-segment depression [5, 10, 11, 16-19, 21-25]. Finally, we should emphasise that according to Pelliccia et al. [26] TWI as an abnormal finding in young healthy athletes may represent the initial expression of underlying cardiomyopathies that may appear many years later associated with adverse outcomes. Thus, it seems wise to closely monitor athletes with such ECG changes.

Prevalence of abnormal ECG was significantly higher in male (8.0%) compared to female (4.7%) athletes in our study, which was consistent with the results of other studies [18]. Lower prevalence of abnormal ECGs in female athletes is likely due to several factors, including the lesser extent of LV remodelling and their lower participation rate in sports that could have an impact on ECG changes.

Having in mind that abnormal ECGs in our athletes were related to more pronounced duration and weekly amount of sport activity as well as with type of the sport (soccer, basketball, martial arts) should implicate that those changes may be a consequence of the more substantial cardiac remodeling associated with intensive exercise conditioning [18, 27, 28].

However, one limitation of our study is that we did not perform echocardiography or another imaging procedure, hence the prevalence of structural heart disease in athletes with ECG abnormalities remained in a sphere of speculation.

In conclusion, knowing that ECG changes in athletes are common and usually reflect the adaptive mechanisms that occur as a consequence of regular and/or sustained physical activity, it is fundamental to identify and understand the ECG changes that may indicate the presence of an underlying pathological cardiac disorder. The prevalence of ECG changes, including abnormalities in athletes in RM exists in such a proportion that should implicate mandatory 12-lead ECG in the pre-participation screening program and further on the regular annual basis to identify the structural cardiac disease that could have a high risk of sudden cardiac death and/or would have prognostic implications.

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