The differences in electrocardiogram interpretation in top-level athletes

Agnieszka A. Jakubiak[1, 2], Krystyna Burkhard-Jagodzińska[3], Wojciech Król[2, 4], Marcin Konopka[2, 4], Dominik Bursa[5], Dariusz Sitkowski[3], Marek Kuch[1, 2], Wojciech Braksator[2, 4]

[1]Department of Cardiology, Hypertension and Internal Disease, Second Faculty of Medicine, Medical University of Warsaw, Warsaw, Poland
[2]Mazovia Brodno Hospital, Warsaw, Poland
[3]Institute of Sport — National Research Institute in Warsaw, Poland
[4]Department of Sports Cardiology and Noninvasive Cardiovascular Imaging, Second Faculty of Medicine, Medical University of Warsaw, Warsaw, Poland
[5]Second Faculty of Medicine, Medical University of Warsaw, Warsaw, Poland

A b s t r a c t

Background: The Ministry of Health in Poland recommends electrocardiogram (ECG)-based cardiovascular screening in athletes, but so far there has been a lack of guidelines on preparticipation assessment. We compared different criteria of ECG screening assessment in a group of top-level athletes.

Aim: The aims were to evaluate the prevalence of ECG changes in athletes that necessitate further cardiological work-up according to three criteria in various age groups as well as to identify factors determining the occurrence of changes related and unrelated to the training.

Methods: 262 high-dynamic, high-static Polish athletes (rowers, cyclists, canoeists) were divided into two age categories: young ($\leq$ 18 years of age; n = 177, mean age 16.9 $\pm$ 0.8; 15–18 years) and elite (> 18 years of age; n = 85, mean age 22.9 $\pm$ 3.4; 19–34 years). All sports persons had a 12-lead ECG performed and evaluated according to 2010 European Society of Cardiology (ESC) recommendations, 2012 Seattle criteria, and 2014 Refined criteria.

Results: The Refined criteria reduced ($p < 0.001$) the number of training-unrelated ECG findings to 8.0% vs. 12.6% (Seattle criteria) and 30.5% (ESC recommendations). All three criteria revealed more training-related changes in the group of older athletes (76.5% vs. 55.9%, $p = 0.001$). Predictors that significantly ($p < 0.005$) affected the occurrence of adaptive changes were the age of the athlete, training duration (in years), and male gender.

Conclusions: 1. The ESC criteria identified a group of athletes that was unacceptably large, as for the screening test, requiring verification with other methods (every fourth athlete). 2. The use of the Refined criteria helps to significantly reduce the frequency and necessity for additional tests. 3. The dependence of adaptive changes on training duration and athletes' age confirms the benign nature of those ECG findings.

Key words: athletes, electrocardiogram, sudden cardiac death, athlete's heart

Kardiol Pol 2017; 75, 6: 535–544

INTRODUCTION

Screening of competitive athletes to prevent sudden cardiac death (SCD) is subject to vast debate among experts from around the world [1]. The physical examination, as well as taking a thorough personal and family history, are very common ways of preparticipation evaluation of athletes [2]. Additional tests, especially the use of electrocardiogram (ECG) in routine screening, remain a contentious issue [3]. In most of European countries, including Poland, ECG screening is recommended.

Sudden cardiac death among athletes is very rare (0.6 in 100,000), but it arouses strong emotions and raises doubts about the positive effect of physical activity on health [4]. Therefore, preventing SCD has not only an individual com-

ponent, but also a significant social impact on physical activity in the general population [5].

In young patients (< 35 years), predominant causes of death are cardiomyopathies and primary electrical heart diseases such as Wolff-Parkinson-White syndrome (WPW) or channelopathies, i.e. diseases that are usually detectable in the ECG [6].

In 2010 the Sports Sections of the European Society of Cardiology (ESC) published a document that proposed the division of athletes' ECG changes into two groups: common, training-related, associated with the degree of training (group 1); and uncommon and training-unrelated (group 2). It was recommended that an athlete with a change from group 1 does not require further evaluation, while an athlete with a change from group 2 should be subjected to further assessment [7]. The main discussed disadvantage of the widespread use of ECG screening is its high number of false-positive results in contrast to the previously mentioned low incidence of SCD [8]. For this reason, in recent years, efforts have been made to modify the criteria for the interpretation of the athletes' ECGs to improve their specificity while retaining high sensitivity for detection of those at risk of SCD. The most widely cited modification is the Seattle criteria, published in 2012 [9].

In 2014 Sheikh et al. [10] proposed further modifications to the interpretation of ECG. They separated the third group of changes called the 'borderline group', thus recognising that selected changes from group 2 according to the ESC (i.e. hypertrophy of the left and right atrium, dextrogram, sinistrogram, and right ventricular hypertrophy [RVH]) would be treated as mild, if presented in isolation. So far there is no available data on the prevalence of ECG changes in the population of Polish athletes according to proposed modifications of ESC criteria.

The aim of this study was to evaluate the prevalence of ECG changes in athletes that necessitate further cardiological work-up according to three different criteria in various age groups. Additionally, an attempt was made to identify factors determining the occurrence of two types of ECG changes (group I and II).

METHODS
Study group

The total study population consisted of 262 top-level athletes, members of the Polish National Team, taking part in sports competitions at national and international levels.

Athletes of high-endurance disciplines (high-static, high-dynamic, IIIC by Mitchell et al. [11]): rowers, cyclists, canoeists — undergoing periodic evaluation in the Institute of Sport — National Research Institute in Warsaw were included in the study. The athletes were divided into two age categories: ≤ 18 years of age (young athletes) and > 18 years of age (elite athletes). The research was carried out in November 2014 (rowers, cyclists), December 2014 (canoeists), and April 2015 (rowers).

Methodology

All athletes underwent cardiovascular screening including a physical examination and taking personal and family history with a emphasis on SCDs before 45 years of age among first- and second-degree relatives. Morphometric (height, body weight) and demographic data were obtained. Then, a 12-lead ECG was performed. All athletes or their guardians gave their informed consent to the study.

Electrocardiography examination

A standard resting 12-lead ECG was performed at least 12 h after the last intensive physical activity. The examination was conducted using a Marquette-Hellige ECG machine with dedicated Cardios-Soft V6.73.2 software by General Electric, USA. The ECG was recorded at 25 mm/s and 10 mm/mV in all participants. The analysis of ECG was performed independently by two investigators. In case of discrepancies, ECG tracings were reviewed again and mutual agreement was obtained. Quantitative measurements including the heart rate (HR; bpm), PR interval, QRS duration, QT interval, corrected QT interval — calculated according to the Bazet's formula, heart axis deviation, P wave duration, P wave amplitude, Q wave amplitude, Q wave duration, R wave amplitude, S wave amplitude, STJ amplitude, STM amplitude, STE amplitude, and T wave amplitude were calculated automatically and then verified by the persons describing the electrocardiograms.

Sinus bradycardia was defined as a resting HR < 60 bpm, first-degree atrioventricular (AV) block as prolonged PR interval (over 200 ms); incomplete right bundle branch block (iRBBB) as an rSR pattern in V1 with QRS duration 110–120 ms. To recognise left ventricular hypertrophy (LVH), the Sokolow-Lyon index (S in V1 + R in V5 or V6 > 35 mm) and Cornell index (S in V3 + R in aVL > 28 mm for male and > 20 mm for female) were used. The ECG tracings were also assessed for the presence of early repolarisation (ER). The ER was defined as elevation of the J point (offset of QRS complex) of at least 0.1 mV in ≥ two adjacent leads in the anterior (V1–V4), the inferior (II, III, aVF), and the lateral (V5, V6, I, aVL) heart wall [12].

A left posterior fascicular block (LPFB) was diagnosed when all the criteria were met: right axis deviation, (+90, +180 degrees), qR complex in III and aVF leads, rS complex in I and aVL leads, time to peak R-wave > 45 ms, QRS complex duration < 120 ms, and lack of RVH. Due to the very large number of ECGs meeting the above criteria in the top-level athletes, taking into account the clinical data, based on the recommendations of the Polish Cardiac Society from 2016, LPFB was not treated as a pathological change [13, 14].

Ventricular pre-excitation (i.e. WPW syndrome) was defined as prolonged QRS complex > 120 ms with delta wave and ST-T wave changes. However, a short-PR interval without delta wave has been reported as a normal variant of an athlete's ECG [7].

All ECG tracings were also assessed for the presence of sinus arrhythmias, supraventricular, junctional, and ventricular arrhythmias.

The classification of ECG abnormalities

The ECG abnormalities not related to sport activity were analysed according to the standards included in the ESC recommendation (2010), the Seattle criteria (2013), and the Refined criteria (2014), which are presented in detail in Table 3. The ECG changes related to training were defined as in the Seattle criteria (Table 4).

Statistical analysis

To process the statistical data, commercially available software Statistica version 12.5 (StatSoft, Tulsa, OK, USA) and Microsoft Office Excel 2007 were used. The data are presented as mean $\pm$ standard deviation (SD). Distribution type variables were tested using the Shapiro-Wilk test. Depending on the nature of the distribution of the variables, comparison of the tested groups was done using t-student's test or the Mann-Whitney test (for quantitative variables) and 2×2 table and χ^2 test (for qualitative variables). Predictors affecting the selected variable were checked by using the analysis of logistic regression. The odds ratio and 95% confidence interval were identified. Values of $p < 0.05$ were considered statistically significant. In the tables, the p-values that did not reach the level of statistical significance were marked as 'NS' (not statistically significant).

RESULTS
General data

The study group consisted of Caucasian athletes: 177 young (including 43.5% females) and 85 elite (including 34.1% females). The subjects did not have any chronic diseases and had negative family history of SCD. Detailed characteristics of the groups are shown in Table 1.

Standard ECG measurements

Mean values and SDs values for selected conventional ECG measurements are presented in Table 2.

Athletes in the elite group had a significantly longer QRS duration than athletes in the young group. Two participants showed QRS duration longer than 140 ms. One of them belonged to the group of young athletes and suffered from WPW syndrome, whereas the second one was from the elite group and showed nonspecific intraventricular conduction delay (IVCD) (QRS 156 ms). They are shown in the Figures 1 and 2.

Among elite athletes a significantly longer QT interval (407.2 $\pm$ 27.5 vs. 421.5 $\pm$ 23.7, $p < 0.001$) occurred, but the two participants with the longest QTc > 500 ms belonged to the young group. There were no differences between the groups comparing the corrected QT interval. None of the athletes showed a QTc that was shorter than 320 ms.

Table 1. Characteristics of the population studied; number (%) or mean $\pm$ standard deviation

	Young	Elite	P
	$\leq$ 18 years	> 18 years	
Athletes	177 (67.5%)	85 (32.5%)	
Sex:			
Female	77 (43.5%)	29 (34.1%)	NS
Male	100 (56.5%)	56 (65,9%)	
Age [years]	16.9 $\pm$ 0.8	22.9 $\pm$ 3.4	< 0.001
Height [cm]	177.9 $\pm$ 9.5	181.4 $\pm$ 10.2	0.005
Weight [kg]	69.9 $\pm$ 11.7	77.3 $\pm$ 12.9	< 0.001
Training duration [h/week]	13.0 $\pm$ 4.1	22.9 $\pm$ 7.3	< 0.001
Training duration [years]	4.3 $\pm$ 1.8	10.6 $\pm$ 3.6	< 0.001

Table 2. The mean values of selected electrocardiogram parameters (mean $\pm$ standard deviation)

	Young	Elite	P
	$\leq$ 18 years	> 18 years	
Heart rate [bpm]	62.1 $\pm$ 10.0	57.2 $\pm$ 8.4	< 0.001
PR interval [ms]	144.2 $\pm$ 19.9	159.5 $\pm$ 30.3	< 0.001
QRS duration [ms]	94.8 $\pm$ 9.8	98.5 $\pm$ 11.3	0.006
QT interval [ms]	407.2 $\pm$ 27.5	421.5 $\pm$ 23.7	< 0.001
Corrected QT int. [ms]	410.7 $\pm$ 24.1	408.4 $\pm$ 22.8	0.46
QRS axis [degrees]	85.8 $\pm$ 20.4	84.3 $\pm$ 23.6	0.59
P-wave duration [ms]	96.0 $\pm$ 10.6	103.0 $\pm$ 11.3	< 0.001

The analysis revealed a longer P-wave and PR interval duration in the elite group: 96.0 $\pm$ 10.6 vs. 103.0 $\pm$ 11.3, $p < 00.1$ and 144.2 $\pm$ 19.9 vs. 159.5 $\pm$ 30.3, $p < 0.001$, respectively. A shorter PR interval duration (< 120 ms) was recorded in 14 (7.9%) young athletes and in two (2.4%) elite athletes ($p = 0.08$). The shortest PR interval, equalling 98 ms, was observed in one female from the young group, who did not meet the criteria of WPW syndrome.

First-degree AV block was seen in 1.7% young athletes and 5.9% elite athletes. The longest PR interval, 324 ms, was observed in one female from the elite group.

Electrocardiographic data analysis and interpretation according to three criteria

Training-unrelated ECG findings. Training-unrelated findings and their definitions according to three current criteria are shown in Table 3.

The numbers of athletes with training-unrelated changes according to ESC, Seattle, and Refined criteria are illustrated in Figure 3.
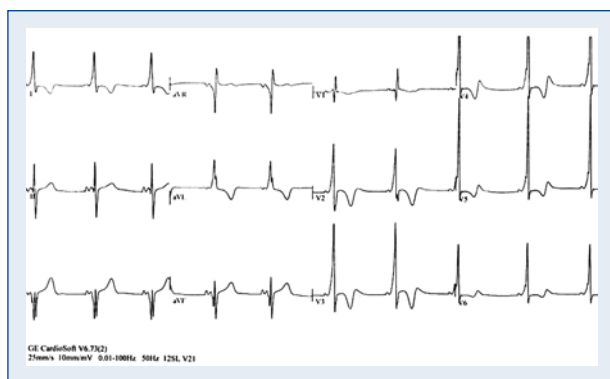
Figure 1. Electrocardiogram of 18-year-old rower with a Wolff-Parkinson-White syndrome

Figure 2. Electrocardiogram of 23-year-old canoeist with intraventricular conduction delay

In total, 89 (34%) athletes were diagnosed with at least one training-unrelated change in ECG. Among them, only 12 (4.6%) participants met all three criteria simultaneously. These athletes revealed the following results: long QTc (n = 4), ST depression (n = 4), IVCD (n = 3), T-wave inversion (TWI) (n = 2), RVH (n = 1), and ventricular pre-excitation (n = 1).

Compared with the ESC recommendations, the use of the Seattle criteria significantly reduced the number of training-unrelated ECGs from 30.5% to 12.6% (a 17.9% reduction; p < 0.001). The application of the Refined criteria caused further reduction down to 8.0% (p < 0.001). The differences were statistically significant.

The percentage of training-unrelated changes occurring in the whole group according to three criteria is illustrated in Figure 4. The percentage distribution of the different changes is shown in Figure 5.

Training-related ECG findings. The frequency of training-related ECG changes is presented in Table 4.

Predictors of ECG changes. The logistic regression analysis demonstrated that predictors that statistically significantly affected the occurrence of adaptive changes were the age of the athletes, training duration (in years), and male gender. The group of elite athletes had a 2.5-times greater chance of occurrence of training-related ECG changes. Each year of training increased the probability of occurrence of training-related ECG changes by 14%. There was no evidence of this type regarding the training-unrelated changes. The only statistically significant variable in the group of pathological changes was male gender: men had a 2.4-times greater chance of revealing training-unrelated findings (Tables 5, 6).

DISCUSSION

Even though ECG-based cardiovascular screening is recommended in Poland by the Ministry of Health and is refunded by the national insurer, hitherto we lack specific recommendations on how to perform the preparticipation assessment. To establish a nationwide strategy, epidemiologic and pharmacoeconomic evaluation is necessary. This paper is the first work that compares different criteria of ECG screening assessment in the group of top-level Polish athletes. The need to adapt the criteria to the population studied (in terms of race, demographics, type of sport) has become a new direction in the study of athletes [15]. The problem was raised by Asif and Prutkin [16] and Prakash and Sharma [17], who ascertained that individualisation of study criteria is the key and the right direction to improve screening with the view of minimising the false positive results and unnecessary disqualification of athletes. The sensitivity of ECG-based screening is unquestionable. Abnormal ECG findings in different cardiomyopathies range from 90% to 100% [18]. On the other hand, the most commonly raised problem is the number of false positive findings and therefore low specificity [19].

The study presents a comprehensive evaluation of ECG changes in the selected group of athletes in two different age-groups. The athletes participating in highly static and highly dynamic disciplines (IIIC by Mitchel et al. [11]) most commonly demonstrate changes classified as "athlete's heart", including the ECG ones [20, 21]. Therefore, the percentage of observed changes in the resting ECG, which require further medical assessment, can be assumed to be the highest possible.

Similarly to other authors, we have shown that the use of different criteria for evaluation of ECG screening significantly lowered the percentage of athletes with ECG changes necessitating further cardiological examination. By using the Seattle criteria, we achieved a 2.5-fold reduction in the occurrence of pathological changes in comparison to ESC criteria, whereas Refined criteria gave a nearly four-fold reduction in comparison to the ESC criteria. Riding et al. [22], in an extensive analysis (2.491 male athletes, different nationalities, different disciplines), obtained very similar results: ESC criteria vs. Seattle criteria revealed an almost 2-fold reduction, and ESC criteria vs. Refined criteria a 4-fold reduction in detection of abnormal changes.

In our study three factors had the greatest impact on the reduction of changes perceived as pathological. These were:

Table 3. Prevalence of training-unrelated electrocardiogram (ECG) findings

Training-unrelated ECG findings	ESC 2010	Seattle 2013	Refined 2014	ESC 2010	Seattle 2013	Refined 2014
T-wave inversion	≥ 2 mm in two adjacent leads (excludes V1, aVR)	> 1 mm in two or more leads (excludes III, aVR, V1)	As Seattle	2 (0.8%)	2 (0.8%)	2 (0.8%)
ST-segment depression	ST depression ≥ 0.5 mm	≥ 0.5 mm in depth in two or more leads	As Seattle	4 (1.5%)	4 (1.5%)	4 (1.5%)
Pathological Q-wave	> 4 mm deep in any lead (except III, aVR)	> 3 mm in depth or > 40 ms in duration in two or more leads (except III and aVR)	≥ 40 ms in duration or ≥ 25% of the height of the ensuing R wave (except III and aVR)	10 (3.8%)	21 (8.0%)	1 (0.4%)
Intraventricular conduction delay	Any QRS > 110 ms including LBBB and RBBB	Any QRS ≥ 140 ms or complete LBBB	As ESC	14 (5.3%)	3 (1.2%)	14 (5.3%)
Left-axis deviation	−30° to −90° or LAH	−30° to −90°	As ESC BORDERLINE	3 (1.2%)	3 (1.2%)	3 (1.2%)
Right-axis deviation	> 110° or LPH	−	> 115° BORDERLINE	7 (2.7%)	−	5 (1.9%)
Left atrial enlargement	Negative portion of the P wave in lead V1 ≥ 0.1 mV in depth and ≥ 40 ms in duration	Prolonged P-wave duration of > 120 ms In leads I or II with negative portion of the P wave ≥ 1 mm in depth and ≥ 40 ms in duration in lead V1	As ESC BORDERLINE	0	0	0
Right atrial enlargement	≥ 2.5 mm in II, III, or aVF	−	As ESC BORDERLINE	7 (2.7%)	−	7 (2.7%)
Right ventricular hypertrophy	R-V1 + S-V5 > 10.5 mm	R-V1 + S-V5 > 10.5 mm and right axis deviation > 120°	As ESC BORDERLINE	7 (2.7%)	1 (0.4%)	7 (2.7%)
Ventricular pre-excitation	PR < 120 ms	PR interval < 120 ms with a delta wave and wide QRS (> 120 ms)	As Seattle	16 (6.1%)	1 (0.4%)	1 (0.4%)
Long QTc	≥ 440 ms in males	≥ 470 ms in males	As Seattle	9 (3.4%)	3 (1.2%)	3 (1.2%)
	≥ 460 ms in females	≥ 480 ms in females		3 (1.2%)	1 (0.4%)	1 (0.4%)
Short QTc	QTc ≤ 380 ms	QTc ≤ 320 ms	−	20 (7.6%)	0	−
Brugada ECG pattern	High take off ≥ 2 mm and downsloping ST segment elevation followed by a negative T wave in ≥ 2 leads in V1–V3	High take off and downsloping ST segment elevation followed by a negative T wave in ≥ 2 leads in V1–V3	As Seattle	0	0	0
Profound sinus bradycardia	−	< 30 bpm or sinus pauses ≥ 3 s	−	−	0	−
Atrial tachyarrhythmia	−	AF, AFL, SVT	As Seattle	−	0	0
Premature ventricular contraction	−	≥ 2 PVCs per 10-s tracing	As Seattle	−	1 (0.4%)	1 (0.4%)
Ventricular arrhythmias	−	Couplets. triplets and nsVT	−	−	0	−
Total abnormal ECGs findings				102	40	27/22 (1) Abnormal findings/ /borderline findings (> 1 border-line finding)
Athletes with abnormal ECG				80 (30.5%)	33 (12.6%)	21 (8.0%)

AF — atrial fibrillation; AFL — atrial flutter; LAH — left anterior hemiblock; LBBB — left bundle branch block; LPH — left posterior hemiblock; nsVT — non-sustained ventricular tachycardia; PVC — premature ventricular contraction; RBBB — right bundle branch block; SVT — supraventricular tachycardia
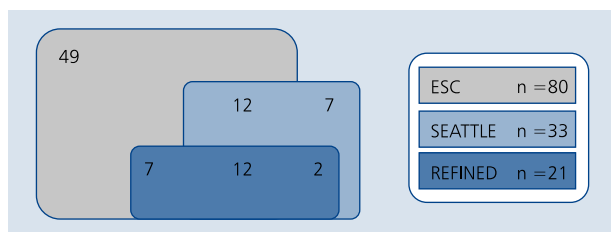
Figure 3. The number of athletes with training-unrelated changes according to three criteria. Boxes contain European Society of Cardiology (ESC), Seattle, and Refined criteria. Overlapped fields contain athletes determined by at least two criteria.
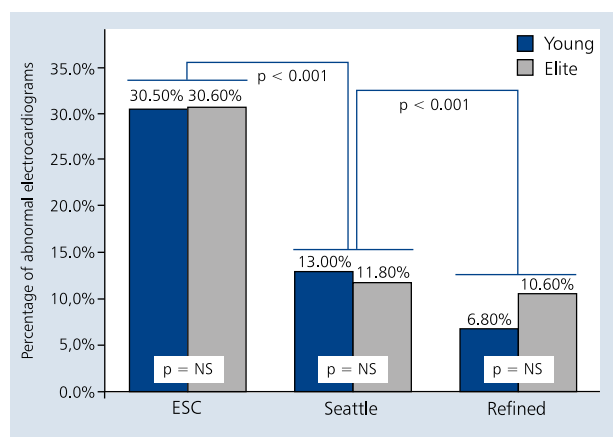

Figure 4. The percentage of the training-unrelated changes according to three criteria. Blue columns — young group of athletes; grey columns — elite group of athletes. Lines and p-values signify statistical significance of differences between European Society of Cardiology (ESC) criteria and Seattle criteria, and Seattle criteria and Refined criteria

lowering of short QT cut-off value to 320 ms (Seattle criteria), expanding the definition of pre-excitation by a "delta wave" (Seattle and Refined criteria), as well as a modification of the definition of a pathological Q (Refined criteria) (Fig. 5).

For the Seattle criteria, the definition of pathological Q-wave to the greatest extent affected the amount of changes requiring further diagnosis. Adopted by Drezner et al. (Seattle criteria), the arbitrary value of Q-wave depth > 3 mm is due to the high specificity (95%) for detecting hypertrophic cardiomyopathy (HCM), but its sensitivity is low (35%) [18].

One way to circumvent this limitation seems to be referring the Q-wave to the R-wave, as suggested in the Refined criteria, namely ≥ 25% of the height of the ensuing R wave.

On the other hand, the guidelines issued by the Polish Society of Cardiology attribute little importance to the amplitude of Q-waves in adolescents and recommend the use of the width of 40 ms. In this study, none of the athletes showed

signs of Q wave > 40 ms of two adjacent leads, and only one person had Q-wave > 25% R-wave in two adjacent leads.

The separation of borderline changes in the Refined criteria was also highly significant. In the borderline group, out of all the athletes examined, only one person met simultaneously the two criteria (RVH and dextrogram) and thus qualified for the group with pathological ECG changes. The remaining 19 athletes presented only one borderline change and therefore did not necessitate any further cardiological work-up. What is worth noticing, in our young population none of the sportsmen examined fulfilled the criteria of left atrial enlargement (LAE), which was postulated as a reason for false positive results of ECG screening in some populations [23]. Surprisingly, the right atrial enlargement (RAE) (which is not perceived as a pathologic finding in the Seattle criteria) was present in seven individuals. Nonetheless, there is weak correlation between ECG parameters and actual atrial size assessed in imaging modalities. These abnormalities are often seen in patients with cardiomyopathies and arrhythmias [24]. LAE is very common in endurance athletes, so some authors suggest additional implementation of new echocardiographic modalities for the functional assessment of left atrium [25, 26].

The proportion of ECG changes requiring further investigation shows some differences, which can be explained by the characteristics of the study group. In our study group the most common ECG "suspected" change according to the Refined criteria was IVCD (5.3%), and the TWI amounted only to 0.8%. Whereas in the work of Sheikh et al. [10], TWI > 3% was the single most common abnormal finding. The discrepancies may be explained by differences in both the ethnicity and the sports disciplines of the populations examined. Athletes of Afro-Caribbean origin, who comprised 20% of Sheikh's study group, are more likely to present TWI than are Caucasians [10, 27]. Many publications based on additional tests such as echocardiography and cardiac magnetic resonance revealed that TWI is closely associated with cardiac diseases, particularly with HCM [28–31]. In the cited paper, the TWI was present in 97% of athletes with diagnosed HCM [10].

Rowin et al. [32] presented the limitation of screening athletes with ECG showing how important the role of medical history and physical examination is. In his work, based on a group of 114 young patients already diagnosed with HCM, he proved that with the use of the ESC recommendation, ECG helped to diagnose the cardiomyopathy only in 90% of patients (n = 103). The remaining 10% (n = 11) did not present any lesions suggesting a pathology in ECG. By raising the problem of false negative results, the author of the cited work demonstrated how imperfect the criteria for ECG analysis are and, at the same time, reminded us that this is only an additional examination. Among the 11 patients (the 10% mentioned above), seven had a family history of HCM, and four presented a systolic cardiac murmur. Similarly,
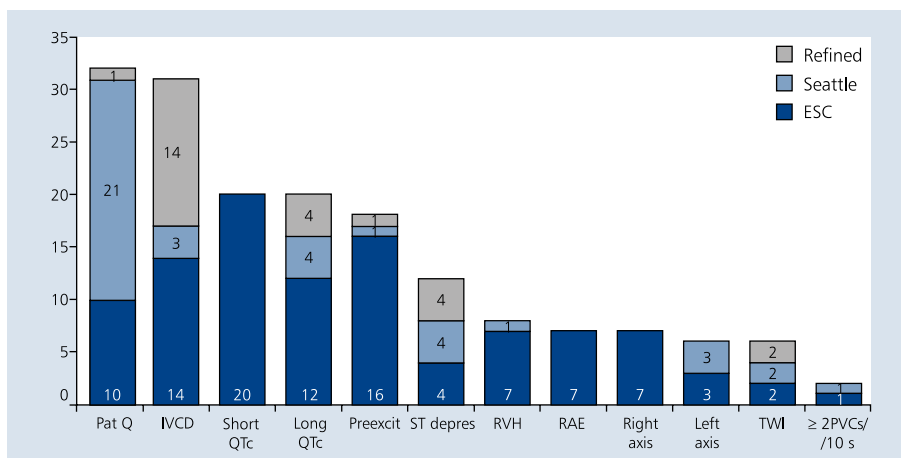
Figure 5. The number of athletes with training-unrelated changes according to three criteria; Pat Q — pathological Q-wave; IVCD — intraventricular conduction delay; Preexcit — ventricular pre-excitation; ST depres — ST-segment depression; RVH — right ventricular hypertrophy; RAE — right atrial enlargement; TWI — T-wave inversion; PVC/10 s — premature ventricular contractions per 10 s

Table 4. Frequency of training-related electrocardiogram (ECG) findings in two different age groups

Training-related ECG findings	Young ≤ 18 years N = 177 (67.5%)	Elite > 18 years N = 85 (32.5%)	P
Sinus bradycardia	16 (9%)	18 (21.2%)	0.006
First-degree AV block	3 (1.7%)	5 (5.9%)	NS
Incomplete RBBB	6 (3.4%)	3 (3.5%)	NS
Early repolarisation	61 (34.5%)	42 (49.4%)	0.02
Isolated QRS voltage criteria for LVH	53 (30.0%)	31 (36.5%)	NS
Sinus arrhythmia	10 (5.6%)	3 (3.5%)	NS
Ectopic atrial rhythm	5 (2.8%)	3 (3.5%)	NS
Junctional escape rhythm	1 (0.6%)	0	NS
Second-degree AV block	0	0	–
Total training-related ECGs findings	155	105	
Athletes with training-related ECG	99 (55.9%)	65 (76.5%)	0.001
Athletes with training-related ECG without any training-unrelated ECG findings	54 (30.5%)	41 (48.2%)	0.005

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

Table 5. Predictive factors associated with the presence of training-related changes according to the three criteria (n = 164 athletes)

Parameter	Training-related ECG finding		
	OR	95% CI	p
Training duration [years]	1.14	1.05–1.23	0.001
Age	1.13	1.04–1.24	0.005
> 18 vs. ≤ 18 years	2.56	1.43–4.59	0.002
Male vs. female	5.07	2.95–8.69	< 0.001

CI — confidence interval; OR — odds ratio

Table 6. Predictive factors associated with the presence of training-unrelated changes according to the three criteria (n = 89 athletes)

Parameter	Training-unrelated ECG finding		
	OR	95% CI	P
Training duration [years]	0.99	0.92–1.06	NS
Age	0.97	0.90–1.04	NS
> 18 vs. ≤ 18 years	0.93	0.54–1.62	NS
Male vs. female	2.44	1.40–4.25	0.002

CI — confidence interval; OR — odds ratio

Riding et al. [22] showed in his paper that heart auscultation helped to identify an additional 1.2% (n = 29) of athletes with valvular heart disease, who did not present pathological changes in ECG.

One of the important findings of our study was that none of three assessed criteria revealed any differences in the occurrence of pathological changes between the young and elite groups. There was also no evidence that the training duration had any impact on the incidence of pathological changes (Table 6). On the contrary, we confirmed that the length of training increased the possibility of adaptive changes in ECG (by 14% for each year of training) (Table 5). Similarly, Brosnan et al. [33] attempted to compare the effects of exercise load on the presence of adaptive changes. They revealed that adaptive changes appeared more frequently in the group of high-endurance athletes than in the non-endurance group: 90.8% vs. 86.0%, respectively (p = 0.04).

In our study, training-related changes occurred in 62.5% of athletes; among them the most common were: ER (35% and 49%, in young and elite, respectively), followed by an isolated LVH (30% and 37%, respectively) and sinus bradycardia (9% and 21%, respectively) (Table 4). The much higher incidence of training-related changes, such as the ones described in the work of Wasfy et al. [34], whose results reached up to 94% of 330 athletes (rowers) studied, can be explained by a different way of defining the most common changes such as iRBBB and ER. Whereas, in our study, in accordance with the recommendations of the Polish Cardiac Society, we limited the iRBBB diagnosis to QRS between 110 ms and 120 ms. Moreover, the criteria for early repolarisation had to be met for at least two adjacent leads from the anterior, inferior, or lateral walls, which is not included in the work of Wasfy et al. [34]. However, Konopka et al. [12], who applied the same criteria that define the ER, noted the change in a comparable percentage of athletes (30%). Regardless of the means of definition, ER is certainly the most common finding in athletes' resting ECG and should be perceived as a norm if no other coexisting suspected conditions are present.

Limitations of the study

One of the limitations of our study is a relatively small group of athletes. However, the studied group was very homogenic in terms of type of physical exercise, which makes our group significant in that class of exercise load. The lack of echocardiography or other imagining modality verification causes an inability to assess the sensitivity and specificity of the criteria related to structural heart disease. Nevertheless, the aim of the study was not to assess the effectiveness of the available criteria for the detection of cardiovascular pathology. Also, the long-term follow-up would help to assess the clinical significance of observed electrocardiographic changes.

CONCLUSIONS

1. The ESC criteria identified a group of athletes, unacceptably large as for the screening test, requiring verification with other methods (every fourth athlete).
2. The use of the Refined criteria helps to significantly reduce the frequency and necessity of additional tests.
3. The dependence of adaptive changes on training duration and athletes' age suggests a benign nature of those ECG findings.

Conflict of interest: *none declared*

References

1. Leischik R, Dworrak B, Foshag P, et al. Pre-participation and follow-up screening of athletes for endurance sport. J Clin Med Res. 2015; 7(6): 385–392, doi: 10.14740/jocmr2129w, indexed in Pubmed: 25883700.
2. Myerburg RJ, Vetter VL. Electrocardiograms should be included in prepartipation screening of athletes. Circulation. 2007; 116(22): 2616–26; discussion 2626, doi: 10.1161/CIRCULATIONAHA.107.733519, indexed in Pubmed: 18040041.
3. Maron BJ, Thompson PD, Ackerman MJ, et al. American Heart Association Council on Nutrition, Physical Activity, and Metabolism. Recommendations and considerations related to prepartipation screening for cardiovascular abnormalities in competitive athletes: 2007 update: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism: endorsed by the American College of Cardiology Foundation. Circulation. 2007; 115(12): 1643–1655, doi: 10.1161/CIRCULATIONAHA.107.181423, indexed in Pubmed: 17353433.
4. Maron BJ, Doerer JJ, Haas TS, et al. Sudden deaths in young competitive athletes: analysis of 1866 deaths in the United States, 1980-2006. Circulation. 2009; 119(8): 1085–1092, doi: 10.1161/CIRCULATIONAHA.108.804617, indexed in Pubmed: 19221222.
5. Leischik R. Endurance sport and cardiac injury. Kardiol Pol. 2014; 72(7): 587–597, doi: 10.5603/KP.a2014.0089, indexed in Pubmed: 24846352.
6. Corrado D, McKenna WJ. Appropriate interpretation of the athlete's electrocardiogram saves lives as well as money. Eur Heart J. 2007; 28(16): 1920–1922, doi: 10.1093/eurheartj/ehm275, indexed in Pubmed: 17623679.
7. Corrado D, Pelliccia A, Heidbuchel H, et al. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. Eur Heart J. 2010; 31(2): 243–259, doi: 10.1093/eurheartj/ehp473, indexed in Pubmed: 19933514.
8. Brosnan M, La Gerche A, Kalman J, et al. The Seattle Criteria increase the specificity of prepartipation ECG screening among elite athletes. Br J Sports Med. 2014; 48(15): 1144–1150, doi: 10.1136/bjsports-2013-092420, indexed in Pubmed: 23813487.
9. Drezner JA, Ackerman MJ, Anderson J, et al. Electrocardiographic interpretation in athletes: the 'Seattle criteria'. Br J Sports Med. 2013; 47(3): 122–124, doi: 10.1136/bjsports-2012-092067, indexed in Pubmed: 23303758.
10. Sheikh N, Papadakis M, Ghani S, et al. Comparison of electrocardiographic criteria for the detection of cardiac abnormalities in elite black and white athletes. Circulation. 2014; 129(16): 1637–1649, doi: 10.1161/CIRCULATIONAHA.113.006179, indexed in Pubmed: 24619464.

11. Mitchell JH, Haskell W, Snell P, et al. Task Force 8: classification of sports. J Am Coll Cardiol. 2005; 45(8): 1364–1367, doi: 10.1016/j.jacc.2005.02.015, indexed in Pubmed: 15837288.

12. Konopka M, Burkhard-Jagodzińska K, Anioł-Strzyżewska K, et al. Prevalence and determinants of the early repolarisation pattern in a group of young high endurance rowers. Kardiol Pol. 2016; 74(3): 289–299, doi: 10.5603/KP.a2015.0133, indexed in Pubmed: 26202527.

13. Swiatowiec A, Król W, Kuch M, et al. Analysis of 12-lead electrocardiogram in top competitive professional athletes in the light of recent guidelines. Kardiol Pol. 2009; 67(10): 1095–1102, indexed in Pubmed: 20017075.

14. Baranowski R, Wojciechowski D, Kozłowski D, et al. [Electrocardiographic criteria for diagnosis of the heart chamber enlargement, necrosis and repolarisation abnormalities including acute coronary syndromes. Experts' group statement of the Working Group on Noninvasive Electrocardiology and Telemedicine of]. Kardiol Pol. 2016; 74(8): 812–819, doi: 10.5603/KP.2016.0119, indexed in Pubmed: 27553353.

15. Pelliccia A. Filling the gap of understanding the athlete's ECG. Eur J Prev Cardiol. 2013; 20(1): 9–11, doi: 10.1177/2047487312467872, indexed in Pubmed: 23258930.

16. Asif IM, Prutkin JM. Modern standards of ECG interpretation in young athletes: yield and effectiveness. J Electrocardiol. 2015; 48(3): 292–297, doi: 10.1016/j.jelectrocard.2014.12.017, indexed in Pubmed: 25595717.

17. Prakash K, Sharma S. Interpretation of the electrocardiogram in athletes. Can J Cardiol. 2016; 32(4): 438–451, doi: 10.1016/j.cjca.2015.10.026, indexed in Pubmed: 26860775.

18. Drezner JA, Ashley E, Baggish AL, et al. Abnormal electrocardiographic findings in athletes: recognising changes suggestive of cardiomyopathy. Br J Sports Med. 2013; 47(3): 137–152, doi: 10.1136/bjsports-2012-092069, indexed in Pubmed: 23303760.

19. Yim ES, Basilico F, Corrado G. Early screening for cardiovascular abnormalities with preparticipation echocardiography: utility of focused physician-operated echocardiography in preparticipation screening of athletes. J Ultrasound Med. 2014; 33(2): 307–313, doi: 10.7863/ultra.33.2.307, indexed in Pubmed: 24449734.

20. Maron BJ, Pelliccia A. The heart of trained athletes: cardiac remodeling and the risks of sports, including sudden death. Circulation. 2006; 114(15): 1633–1644, doi: 10.1161/circulationaha.106.613562.

21. Konopka M, Krol W, Burkhard-Jagodzinska K, et al. Echocardiographic assessment of right ventricle adaptation to endurance training in young rowers - speckle tracking echocardiography. Biol Sport. 2016; 33(4): 335–343, doi: 10.5604/20831862.1216659, indexed in Pubmed: 28090137.

22. Riding NR, Sheikh N, Adamuz C, et al. Comparison of three current sets of electrocardiographic interpretation criteria for use in screening athletes. Heart. 2015; 101(5): 384–390, doi: 10.1136/heartjnl-2014-306437, indexed in Pubmed: 25502812.

23. Gati S, Sheikh N, Ghani S, et al. Should axis deviation or atrial enlargement be categorised as abnormal in young athletes? The athlete's electrocardiogram: time for re-appraisal of markers of pathology. Eur Heart J. 2013; 34(47): 3641–3648, doi: 10.1093/eurheartj/eht390, indexed in Pubmed: 24057078.

24. Sanchis-Gomar F, Perez-Quilis C, Lippi G, et al. Atrial fibrillation in highly trained endurance athletes - Description of a syndrome. Int J Cardiol. 2017; 226: 11–20, doi: 10.1016/j.ijcard.2016.10.047, indexed in Pubmed: 27776250.

25. Leischik R, Littwitz H, Dworrak B, et al. Echocardiographic evaluation of left atrial mechanics: function, history, novel techniques, advantages, and pitfalls. Biomed Res Int. 2015; 2015: 765921, doi: 10.1155/2015/765921, indexed in Pubmed: 26236735.

26. Król W, Jędrzejewska I, Konopka M, et al. Left Atrial Enlargement in Young High-Level Endurance Athletes — Another Sign of Athlete's Heart? J Hum Kinet. 2016; 53: 81–90, doi: 10.1515/hukin-2016-0012, indexed in Pubmed: 28149413.

27. Rawlins J, Carre F, Kervio G, et al. Ethnic differences in physiological cardiac adaptation to intense physical exercise in highly trained female athletes. Circulation. 2010; 121(9): 1078–1085, doi: 10.1161/CIRCULATIONAHA.109.917211, indexed in Pubmed: 20176985.

28. Wilson MG, Carré F. What's the big deal about T-wave inversion in athletes? A guide to clinical interpretation. Br J Sports Med. 2016; 50(2): 72–73, doi: 10.1136/bjsports-2015-094636, indexed in Pubmed: 25869094.

29. Calò L, Sperandii F, Martino A, et al. Echocardiographic findings in 2261 peri-pubertal athletes with or without inverted T waves at electrocardiogram. Heart. 2015; 101(3): 193–200, doi: 10.1136/heartjnl-2014-306110, indexed in Pubmed: 25381327.

30. Zaidi A, Ghani S, Sheikh N, et al. Clinical significance of electrocardiographic right ventricular hypertrophy in athletes: comparison with arrhythmogenic right ventricular cardiomyopathy and pulmonary hypertension. Eur Heart J. 2013; 34(47): 3649–3656, doi: 10.1093/eurheartj/eht391, indexed in Pubmed: 24046435.

31. Thompson AJ, Cannon BC, Wackel PL, et al. Electrocardiographic abnormalities in elite high school athletes: comparison to adolescent hypertrophic cardiomyopathy. Br J Sports Med. 2016; 50(2): 105–110, doi: 10.1136/bjsports-2015-094880, indexed in Pubmed: 26729893.

32. Rowin EJ, Maron BJ, Appelbaum E, et al. Significance of false negative electrocardiograms in preparticipation screening of athletes for hypertrophic cardiomyopathy. Am J Cardiol. 2012; 110(7): 1027–1032, doi: 10.1016/j.amjcard.2012.05.035, indexed in Pubmed: 22809754.

33. Brosnan M, La Gerche A, Kalman J, et al. Comparison of frequency of significant electrocardiographic abnormalities in endurance versus nonendurance athletes. Am J Cardiol. 2014; 113(9): 1567–1573, doi: 10.1016/j.amjcard.2014.01.438, indexed in Pubmed: 24641963.

34. Wasfy MM, DeLuca J, Wang F, et al. ECG findings in competitive rowers: normative data and the prevalence of abnormalities using contemporary screening recommendations. Br J Sports Med. 2015; 49(3): 200–206, doi: 10.1136/bjsports-2014-093919, indexed in Pubmed: 25202138.

Interpretacja elektrokardiogramu u sportowców wyczynowych

Agnieszka A. Jakubiak[1, 2], Krystyna Burkhard-Jagodzińska[3], Wojciech Król[2, 4], Marcin Konopka[2, 4], Dominik Bursa[5], Dariusz Sitkowski[3], Marek Kuch[1, 2], Wojciech Braksator[2, 4]

[1]Klinika Kardiologii, II Wydział Lekarski, Warszawski Uniwersytet Medyczny, Warszawa
[2]Mazowiecki Szpital Bródnowski, Warszawa
[3]Instytut Sportu w Warszawie, Państwowy Instytut Badawczy, Warszawa
[4]Zakład Kardiologii Sportowej i Nieinwazyjnej Diagnostyki Kardiologicznej, II Wydział Lekarski, Warszawski Uniwersytet Medyczny, Warszawa
[5]II Wydział Lekarski, Warszawski Uniwersytet Medyczny, Warszawa

Streszczenie

Wstęp: Ministerstwo Zdrowia w Polsce rekomenduje wykonywanie elektrokardiograficznych (EKG) badań przesiewowych u sportowców, wciąż jednak brakuje wytycznych na temat tego, które kryteria powinno się stosować w ocenie EKG sportowca. Porównano zatem różne kryteria oceny EKG u polskich sportowców trenujących w wymiarze wyczynowym.

Cel: Celem pracy była ocena częstości występowania zmian w EKG niezwiązanych z treningiem, wymagających dalszej diagnostyki zgodnie z trzema wybranymi kryteriami oceny EKG w dwóch grupach wiekowych. Ponadto podjęto próbę zidentyfikowania czynników determinujących występowanie zmian związanych i niezwiązanych z treningiem.

Metody: 262 polskich sportowców obciążonych największym wysiłkiem dynamicznym i statycznym (wioślarze, kolarze, kajakarze) zostało podzielonych na dwie grupy wg wieku: młodzi (≤ 18 rż.; n = 177, średnia wieku 16,9 ± 0,8 roku; 15–18 lat) oraz dojrzali (> 18 rż.; n = 85, średnia wieku 22,9 ± 3,4 roku; 19–34 lat). U wszystkich sportowców wykonano 12-odprowadzeniowe EKG, które ocenione wg wzorców zawartych w rekomendacjach Europejskiego Towarzystwa Kardiologicznego (ESC) z 2010 r., kryteriów Seattle z 2012 r. oraz kryteriów Refined z 2014 r.

Wyniki: Kryteria Refined obniżyły (p < 0,001) liczbę zmian niezwiązanych z treningiem do 8,0% vs. 12,6% (kryteria Seattle) oraz 30,5% (rekomendacje ESC). Wszystkie trzy kryteria pokazały, że zmiany związane z treningiem występują częściej w grupie starszych sportowców (76,5% *vs.* 55,9%; p = 0,001). Czynnikami wpływającymi (p < 0,005) na występowanie zmian związanych z treningiem w EKG okazały się: wiek sportowca, czas trwania treningu (w latach) i płeć męska.

Wnioski: 1. Ocena wg kryteriów ESC pozwoliła na zidentyfikowanie nieakceptowalnie dużej grupy sportowców wymagających dalszej diagnostyki kardiologicznej (co czwarty badany sportowiec). 2. Zastosowanie kryteriów Refined istotnie zmniejszyło częstość i konieczność wykonywania dodatkowych badań. 3. Zależność częstości występowania zmian związanych z treningiem od czasu trwania treningu oraz od wieku sportowca potwierdza łagodny charakter tych zmian w EKG.

Słowa kluczowe: sportowcy, elektrokardiogram, nagły zgon sercowy, serce sportowca

Kardiol Pol 2017; 75, 6: 535–544