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Benefits and limitations of electrocardiographic and echocardiographic screening in top level endurance athletes

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ABSTRACT: The study was designed to assess the usefulness of routine electrocardiography (ECG) as well as transthoracic echocardiography (TTE) in screening top level endurance athletes. An additional goal was to attempt to identify factors determining occurrence of adaptive and abnormal changes in ECG and TTE. The retrospective analysis included basic medical data, ECG and TTE results of 262 athletes (123 rowers, 32 canoeists and 107 cyclists), members of the Polish National Team. The athletes were divided into two age groups: young ($\leq$ 18 years; n = 177) and elite (> 18 years; n = 85). ECG and TTE measurements were analysed according to the International Recommendations from 2017 and 2015, respectively. Adaptive ECG changes were found in 165 (63%) athletes. Abnormal ECG changes were identified in 10 (3.8%) athletes. 98% of athletes exceeded TTE norms for the general population and 26% exceeded norms for athletes. The occurrence of both adaptive ECG findings and abnormalities in the TTE (in norms for athletes) was strongly associated with the years of training, hours of training per week and the age of the athlete. Male gender and the years of training were independent predictors of the ECG and TTE findings. Abnormal ECG changes were not related to the time of sport. Among 10 athletes with ECG changes, only 3 had changes in TTE and no relationship was found between abnormal finding in ECG and TTE (p = 0.45). ECG and TTE screening complement each other in identifying endurance athletes requiring treatment or verification. Unlike abnormal ECG changes, adaptive ECG changes and TTE abnormalities are strongly related to the training duration, which reflects physiological adaptation of the heart to physical exertion in high endurance athletes.

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INTRODUCTION

Regular and long-term participation in intensive exercise is associated with myocardial remodelling called 'athlete's heart' [1]. The degree of adaptive reconstruction depends on exercise load in relation to the type of sports discipline, the duration of training over the years and the predisposition of the competitor. According to the Pelliccia et al. classification, in high endurance sports – such as cycling, canoeing and rowing, which have high isometric and isotonic components – the greatest remodelling of the heart muscle occurs [2]. In medicine, especially in sports cardiology, the most important challenge for doctors is to correctly distinguish the athlete's heart from pathological conditions that may have similar electrocardiographic and morphological features. On one hand, overlooking diseases associated with an increased risk of sudden death can entail fatal consequences, while on the other hand unnecessary disqualification of an athlete from competitive sports has adverse psychological and financial consequences. Unfortunately, it is not rare that establishing the border between these two states is very difficult or even impossible. The study focused on electrographic and echocardiographic results of 262 Polish athletes practising disciplines which influence the circulatory system the most. The aim of the study was to assess the usefulness of these two tests in screening top-level athletes. The next goal of the study was to attempt to identify factors determining occurrences of adaptive and abnormal changes in electrocardiography (ECG) and transthoracic echocardiography (TTE).

MATERIALS AND METHODS

Group characteristics

The retrospective study was based on data from a medical examination, anthropometric results, electrocardiograms and echocardiographic examinations of rowers, canoeists and cyclists who were members of the Polish National Team. They were competing in national and international sports competitions. The results arose from periodic check-ups carried out in the Institute of Sport – National Research Institute in Warsaw, in 2014 and 2015. The athletes were divided into two age groups of ≤ 18 years (young) and > 18 years (elite).

Electrocardiographic examination

A standard resting 12-lead ECG was performed using a Marquette-Hellige, Cardio-Soft V6.73/2 device from General Electric USA. All ECGs were recorded at 25 mm/s and 10 mm/mV. Each ECG was analysed according to the standards of the International Recommendations for ECG Interpretation in Athletes from 2017 (ESC 2017) [3]. The abnormalities were divided into adaptive, borderline and pathological changes.

Echocardiographic examination

A 2D TTE was performed using the Vivid 7 device (GE Vingmed Ultrasound AS, USA) and M4S probe (1.5–4.0 MHz) with simultaneous ECG (single-lead) recording. The results were analysed on an external computer (offline) using dedicated software (Echo PAC version 112; GE Healthcare, Wauwatosa, WI, USA). All measurements were made in accordance with the echocardiographic international recommendations from 2015 [4, 5]. Echocardiographic norms for the general population and also for athletes are presented in Table 4. The analysis of ECG and TTE was performed by one doctor (AJ). In case of doubt, ECG tracings were reviewed again with another doctor (MK) and mutual agreement was obtained.

Statistic analysis

The results were analysed in Statistica version 13.1 with a medical add-on. Distribution of variables was checked with Shapiro-Wilk test. Data are presented as mean ± standard deviation (M ± SD) or median (interquartile range) (Md (IQR)). Comparison of groups was performed using Student's t-test or the Mann-Whitney U test for quantitative variables and a 2 x 2 table and chi^2 test for qualitative features. The multifactorial models were based on backward stepwise regression to determine independent predictive factors. Analysis of variance (ANOVA) was used to assess the differences in the grouped results. Statistical significance was determined by a value of $p < 0.05$.

RESULTS

Overall, 262 athletes, 177 young (≤ 18 years of age) and 85 elite (> 18 years of age) from three disciplines were examined: 123 rowers, 32 canoeists and 107 cyclists. Women constituted 40.5% of all athletes. The competitors had no chronic diseases and none of them had any family history of sudden cardiac death. Median age in the young group was 17(2) years and in the elite group was 23(4) years.

Normal ECG findings in athletes

Training-related (normal) changes were observed in 165 (63%) athletes. In the young group of athletes such changes were observed in 56% and in the elite 77% of competitors. The most common findings were early repolarization syndrome (39%), isolated left ventricular hypertrophy (32%) and sinus bradycardia (13%). The incidence of normal ECG findings is shown in Table 1.

Abnormal ECG findings in athletes

Non-training related (abnormal) changes were identified in 10 (3.8%) athletes. Particular parameters evaluated in the criteria along with their definitions and the number of athletes who met the given parameter are presented in Table 2.

Predictive factors for the occurrence of normal and abnormal findings in the ECG

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 higher odds for having a normal ECG finding. Each year of training increased the likelihood of these changes by 14%. Male gender and years of training were found to be independent predictors of normal ECG findings. No relationship was found between abnormal ECG findings and the time of sport.

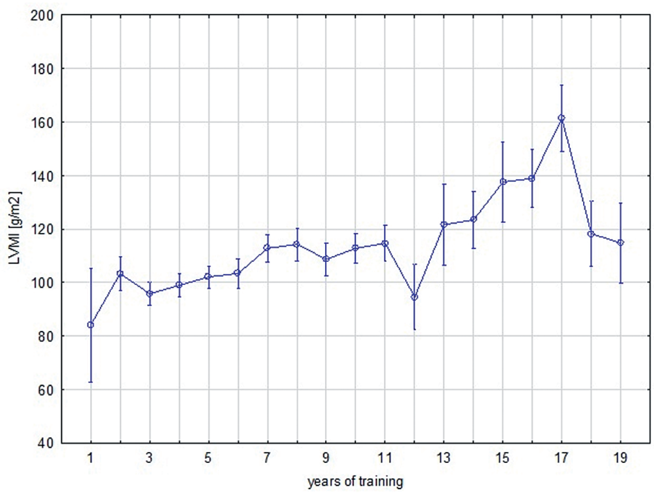

FIG. 1. Left ventricular mass index (LVMI) values in the studied group depending on the years of training (ANOVA). LVMI values: mean (circles) ± standard error (vertical bars), $p < 0.001$.

TABLE 1. Normal ECG findings in the athletes according to the ESC 2017 criteria, divided by age groups.

Normal ECG findings	Definition	Young n = 177 (%)	Elite n = 85 (%)	P – value
Juvenile T-wave pattern	T-wave inversion V1–V3 in athletes age < 16 years	0	-	-
Sinus bradycardia	≥ 30/min	16 (9%)	18 (21.2%)	< 0.05
Incomplete right bundle branch block	QRS < 120 ms, rSR' in lead V1 and qRS in lead V6	6 (3.4%)	3 (3.5%)	NS
Early repolarization	J-point elevation, ST-segment elevation, J waves or terminal QRS slurring in the inferior and/or lateral leads	61 (34.5%)	42 (49.4%)	< 0.05
Isolated QRS voltage criteria for left ventricular hypertrophy (LVH)	SV1+RV5 or RV6 > 3.5 mV	53 (30%)	31 (36.5%)	NS
Isolated QRS voltage criteria for right ventricular hypertrophy (RVH)	RV1+SV5 or SV6 > 1.1 mV	6 (3.4%)	1 (1.2%)	NS
Sinus arrhythmia	Heart rate variation with respiration: rate increases during inspiration and decreases during expiration	10 (5.6%)	3 (3.5%)	NS
Ectopic atrial rhythm	P waves are a different morphology compared with the sinus P-wave, such as negative P waves in the inferior leads	5 (2.8%)	3 (3.5%)	NS
Junctional escape rhythm	QRS rate is faster than the resting P-wave or sinus rate and typically < 100/min with narrow QRS complex unless the baseline QRS is conducted with aberrancy	1 (0.6%)	0	NS
1° AV block	PR interval 200–400 ms	3 (1.7%)	5 (5.9%)	NS
Mobitz Type I (Wenckebach) 2° AV block	PR interval progressively lengthens until there is a non-conducted P-wave with no QRS complex	0	0	-
In total				
Number of normal (adaptive) ECG findings		161	106	-
Number of athletes with normal (adaptive) ECG findings		100 (56%)	65 (77%)	0.002
Number of athletes with only normal (adaptive) ECG findings (without abnormal ECG findings)		97 (54.8%)	61 (71.8%)	0.008

Abbreviations: NS – not statistically significant; AV – atrioventricular

Echocardiographic analysis

All athletes who underwent ECG also underwent TTE. A total of 219 out of 262 echocardiographic images were interpreted. Detailed results broken down by age groups are presented in Table 3. Elite athletes were characterized by much thicker muscle, greater left ventricle mass and larger dimensions of heart chambers – Table 3.

Average left ventricular mass index (LVMI) values increased in successive years of training sports. Reduced values were observed in the athletes who trained 18 and 19 years, which resulted from the predominance of women in these groups – Figure 1.

Left ventricle remodelling

The type of left ventricular remodelling was assessed according to the work of Ganau et al. [6]. The group of elite athletes was characterized by significantly more frequent concentric hypertrophy than the group of young athletes (48.1% compared to 22.9%, $p < 0.001$). On the other hand, the group of young athletes significantly more

TABLE 2. Non-training related (abnormal) ECG findings in the athletes according to the ESC 2017 criteria.

ECG findings	Definition	n (%)
Abnormal in athletes		
T wave inversion	≥ 1 mm in depth in two or more contiguous leads; excludes leads aVR, III, V1	2 (0.8%)
ST segment depression	≥ 0.5 mm in depth in two or more contiguous leads	4 (1.5%)
Pathologic Q wave	Q/R ≥ 0.25 or ≥ 40 ms in duration in two or more leads (excluding III, aVR)	1 (0.4%)
Complete left bundle branch block	QRS ≥ 120 ms, predominantly negative QRS complex in lead V1 (QS or rS), and upright notched or slurred R wave in leads I and V6.	1 (0.4%)
Profound nonspecific intra-ventricular conduction delay	Any QRS duration ≥ 140 ms	2 (0.8%)
Ventricular pre-excitation	PR interval < 120 ms with delta wave (slurred upstroke in the QRS complex) and wide QRS ≥ 120 ms	1 (0.4%)
Epsilon wave	Distinct low signal (small positive deflection or notch) between the end of the QRS complex and onset of the T wave in leads V1–V3.	0
Prolonged QT interval	QTc ≥ 470 ms (male) QTc ≥ 480 ms (female)	3 (1.2%) 1 (0.4%)
Profound sinus bradycardia	< 30/min or sinus pauses ≥ 3 s.	0
Profound 1° AV block	≥ 400 ms	0
Mobitz Type II 2° AV block	Intermittently non-conducted P waves with a fixed PR interval	0
3° AV block	Complete heart block	0
Brugada Type 1 pattern	Coved pattern: initial ST-segment elevation ≥ 2 mm (high take-off) with downsloping ST-segment elevation followed by a negative symmetric T-wave in ≥ 1 leads in V1–V3	0
Atrial tachyarrhythmias	Atrial fibrillation, atrial flutter, supraventricular tachycardia	0
Ventricular arrhythmias	Couplets, triplets, non-sustained ventricular tachycardia	0
Premature ventricular contraction (PVC)	≥ 2 PVCs per 10 s tracing	1 (0.4%)
Borderline in athletes		
Left axis deviation	-30^0 – -90^0	3 (1.2%)
Right axis deviation	> 120^0	5 (1.9%)
Left atrial enlargement	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	0
Right atrial enlargement	P-wave ≥ 2.5 mm in II, III or aVF	7 (2.7%)
Complete right bundle branch block	rSR' pattern in lead V1 and a S wave wider than R wave in lead V6 with QRS duration ≥ 120 ms	0
In total		
Number of abnormal/ borderline ECG findings		16 / 15
Number of the athletes with abnormal/borderline ECG findings	The athletes with ≥ 1 pathological ECG findings or ≥ 2 borderline findings	10 (3.8%)

Abbreviations: AV block – atrioventricular block often than adults showed normal heart geometry (35.7% compared to 15.2%, $p < 0.01$).

Abnormal TTE result according to reference values for the general population and for athletes

As many as 98.2% of the examined athletes exceeded echocardiographic norms for the general population. Moreover, about a quarter of them (i.e. 26%) exceeded even norms for athletes, mainly a dimension of the ventricular septum over 12 mm (24.2%) – Table 4.

The occurrence of abnormalities in echocardiography, namely exceeding the reference values for athletes in the measurements, was strongly associated with belonging to specific age groups, elite athletes much more frequently presented deviations than young ones, respectively 46% compared to 15%, $p < 0.001$. In the logistic regression it was found that 1 year of training increased the odds of the occurrence of norms for athletes being exceeded by 24% [OR = 1.24], $p < 0.001$ – Table 5.

As in the case of normal ECG findings, the occurrence of abnormalities in the TTE examination was strongly associated with the years of training, hours of training per week and the age of the athlete. Moreover, the group of elite athletes had over 4.5 times greater chance of abnormalities being revealed in the TTE examination than the young ones. The strongest independent predictors of exceeding the echocardiographic norms for athletes were male gender and the years of training – Table 5.

TABLE 3. Echocardiographic measurements divided into two age groups of the athletes.

Parameter	Young		Elite		P-value
	Md	IQR	Md	IQR	
Right ventricle and right atrium measurements					
RVD1 [cm]	4.1	0.6	4.3	0.6	NS
RVD2 [cm]	2.3	0.6	2.6	0.8	< 0.001
RVD3 [cm]	9	1.2	9	1.8	NS
RVOT PROX [cm]	3	0.4	3.1	0.3	NS
MPA [cm]	2.2	0.3	2.1	0.3	0.03
RAA [cm^2]	16.2	5.1	19	6.2	< 0.001
RAVI [cm^3/m^2]	24.7	8.7	29.6	14.1	< 0.001
Left ventricle and left atrium measurements					
LVED [cm]	4.9	0.5	5.1	0.5	< 0.001
IVSD [cm]	1	0.2	1.2	0.2	< 0.001
PWD [cm]	1	0.2	1.2	0.2	< 0.001
LVMI [g/m^2]	101.2	24.7	115.5	32.7	< 0.001
LA [cm]	3.4	0.4	3.6	0.4	< 0.001
LAA [cm^2]	18.7	4.5	21.8	6	< 0.001
LAVI [cm^3]	29.5	7.8	33.9	8.6	< 0.001
AoI [cm/m^2]	1.6	0.2	1.6	0.2	NS

Abbreviations: shown in the table 4

Abnormal ECG findings and abnormal result of TTE examination according to reference values for athletes

In the group of 10 athletes who presented an abnormal ECG (according to the ESC 2017 criteria) 8 also underwent TTE and among them 3 presented an abnormal TTE result according to norms for athletes. There was no relationship between the occurrence of abnormal ECG findings and exceeding echocardiographic norms for athletes (chi-square test: abnormal ECG findings vs abnormal TTE according to athletes norms, $p = 0.45$).

DISCUSSION

The study showed that high-performance athletes practising endurance disciplines manifest significant changes in the heart. Almost all the assessed athletes (98.3%) exceeded at least one echocardiographic norm used for the general population and most of them (63%) had normal findings in the ECG.

In analyses aimed at identifying predictive factors for ECG and echocardiographic changes, it was found that both normal ECG findings and exceeded echocardiographic norms depended on identical variables related to the time of training such as belonging to the group of elite athletes, training duration (in years), age and training intensity.

It was also found that the group of elite athletes had a 2.5 times higher odds for having normal findings in the ECG and over 4.5 times greater odds for exceeding norms in TTE, and each year of training increased the likelihood of these changes by 14% and 24%, respectively. In addition, it was found that among normal ECG changes bradycardia and early repolarization (ER) were more common in the elite athletes, probably due to increased vagal tone/parasympathetic activity in this age group. Similarly, Brosnan et al. observed that competitive athletes more often present normal, training-related ECG changes than non-competitive athletes, which might confirm the relationship of these changes with physical effort [8]. At the same time, pathological ECG changes have not been shown to be related to the duration of training.

Utility of ECG or TTE screening in a group of the highest endurance athletes

As can be seen from the presented data, enlarged heart chambers and left ventricle hypertrophy were not uncommon. Every fourth athlete showed significant deviations, which mostly concerned the size of the ventricular septum. Interventricular septum hypertrophy (IVS thickness ≥ 13 mm) was found in 8.7% of the competitors, which significantly differed from the average dimensions observed in competitors of other disciplines, where septal hypertrophy usually affected 2% of athletes [2, 9, 10].

The explanation for the differences can be found in the study of Pelliccia et al. In 1991 he examined a large group of highly trained

TABLE 4. Abnormal echocardiographic results in the studied group according to the reference values for the general population and also for athletes [4, 5, 7].

Parameter	Reference values for the population	Number of athletes who exceeded the norms, n (%)	Reference values for athletes	Number of athletes who exceeded the norms, n (%)
Interventricular Septum IVS [mm]	M 6–10 F 6–9	111 (50.7%) 57 (26%)	< 12 [> 15]	53 (24.2%) [2 (0.9%)]
Posterior Wall Thickness at end-diastole PWD [mm]	M 6–10 F 6–9	115 (52.5%) 67 (30.6%)	–	
LV Mass Indexed to body surface area LVMI [g/m^2]	M 49–115 F 43–95	64 (29.2%) 38 (17.4%)	–	–
LV End-Diastolic Dimension LVED [mm]	M 42–58 F 38–52	9 (4.1%) 7 (3.2%)	< 60	4 (1.8%)
Aorta, Ao [mm]	M < 37 F < 33	11 (5%) 1 (0.5%)	–	
Aorta Index Ao/BSA[cm/m^2]	M 1,9 F 2	4 (1.8%) 3 (1.4%)	–	
Left Atrium LA [mm]	M < 40 F < 38	18 (8.2%) 6 (2.7%)	M < 50 F < 45	0 0
Left Atrium Area LAA [cm^2]	< 20	95 (43.4%)	–	
Left Atrium Volume Index LAVI [mL/m^2]	< 34	76 (34.7%)	–	–
Right Atrium Area RAA [cm^2]	< 18	91 (41.6%)	–	
Right Atrium Volume Index RAVI [mL/m^2]	M 32 F 27	45 (20.5%) 15 (6.8%)	–	
Right Ventricular Diameter 1 RVD1 [mm]	21–41	123 (56.2%)	F < 49 M < 55	2 (0.9%) 2 (0.9%)
Right Ventricular Diameter 2 RVD2 [mm]	19–35	4 (1.8%)	F < 43 M < 47	0 0
Right Ventricular Diameter 3 RVD3 [mm]	59–83	169 (77.2%)	F < 100 M < 109	0 3 (1.4%)
Right Ventricular Outflow Tract RVOT prox [mm]	21–35	23 (10.5%)	F < 40 M < 43	0 0
Main Pulmonary Artery MPA [mm]	15–21	124 (56.6%)	–	
In total		N = 215/219 (98.2%)		N = 57/219 (26%)

TABLE 5. Predictive factors of occurrence of normal and pathological ECG changes as well as abnormal echocardiographic results in the athletes.

Variables	Normal ECG findings			Abnormal ECG findings			Abnormal TTE result		
	OR	95%CI	P value	OR	95%CI	P value	OR	95%CI	P value
				Univariate logistic regression					
Qualitative									
gender male/female	5.07	2.95–8.69	< 0.01	1.02	0.28–3.71	NS	6.63	2.84–15.5	< 0.001
age group: elite/young	2.56	1.43–4.59	0.02	3.29	0.9–11.97	NS	4.74	2.5–9	< 0.001
Quantitative									
years of training	1.14	1.05–1.24	< 0.01	1.11	0.96– 1.27	NS	1.24	1.14–1.35	< 0.001
age	1.14	1.04–1.25	< 0.01	1.10	0.95–1.27	NS	1.31	1.19–1.44	< 0.001
time of raining [hours per week]	1.08	1.03–1.13	< 0.01	1.05	0.97– 1.14	NS	1.1	1.06–1.15	< 0.001
height [cm]	1.06	1.03–1.09	< 0.001	1.01	0.95– 1.08	NS	1.12	1.08–1.17	< 0.001
weight [kg]	1.04	1.02–1.07	< 0.001	1.03	0.98– 1.08	NS	1.12	1.08–1.16	< 0.001
HR [per min]	0.93	0.9–0.96	< 0.001	1.03	0.97– 1.09	NS	0.97	0.94–0.99	0.04
QRS wave [ms]	1.08	1.04–1.12	< 0.001	1.07	1.02– 1.11	< 0.01	1.1	1.06–1.14	< 0.001
				Multivariate logistic regression					
gender male/female	4.59	2.64–8	< 0.001	-	-	-	7.99	3.08–20.7	< 0.001
years of training	1.12	1.04–1.22	< 0.01	-	-	-	1.28	1.16–1.40	< 0.001

Abbreviations: OR – odds ratio; 95%CI – *95% confidence interval;* HR – heart rate

athletes and only 1.7% of them presented a septum size over 13 mm. However, in a detailed analysis of the subgroups in the aforementioned study it emerged that rowers, canoeists, cyclists, i.e. high endurance athletes, had similar results (7%) to those obtained in the present study [11, 12].

This confirms the thesis about the more frequent occurrence of deviations in the group of athletes exposed to the largest static and dynamic loads and significant differences even compared to athletes of other high endurance disciplines.

The examined athletes were characterized by the increased mass of the left ventricle. Almost half of the competitors exceeded the norm for left ventricular mass (LVMI). The average LVMI in individual years of training differed significantly and showed an upward trend. Concentric hypertrophy (relative wall thickness (RWT) > 0.42 and LVMI > 95 g/m^2 females, > 115 g/m^2 males) was found in 68.7% of the competitors. This indicates that athletes training sport disciplines with the highest dynamic and static load perform efforts with a very significant strength component.

Mantziari et al. examining 15 competitive rowers made a similar observation [13]. Also Leishik et al. in a study on triathletes found that despite the expected athletes' heart geometry driven towards eccentric hypertrophy, concentric hypertrophy occurred in most cases and mostly concerned male athletes [14].

However, the theory of concentric hypertrophy in healthy athletes is controversial. There are opinions that, as there are no sports disciplines characterized by only one type of heart load, the four left ventricular geometry patterns seem to be artificial and the term concentric hypertrophy in the context of the adaptation of the athlete's heart should be used with caution because it closely suggests hypertrophic cardiomyopathy (HCM) [15, 16].

One of the aims of the study was the parallel assessment of the usefulness of the two diagnostic methods in the evaluation of sport-dependent heart remodelling. As part of electrocardiographic screening, 10 athletes with significant pathology were examined, including four with Wolff-Parkinson-White Syndrome (WPW) and long QT (LQT) who had a potential threat to life and health. They were covered by specialist care. Others presented intraventricular conduction disturbances, T wave inversion, and ST segment depression. According to experts, such changes suggest congenital or acquired heart disease [3].

The above-mentioned athletes were evaluated with TTE examination – three had interventricular septum hypertrophy (IVS > 12 mm), including one with a dimension over 15 mm (Figure 2). Nevertheless, in a group of highly trained endurance athletes, changes imitating cardiomyopathies may result from advanced remodelling [17].

Sharma et al. noted that physiology and pathology interpenetrate and can be difficult to distinguish especially in cases where there is advanced adaptation in response to the highest efforts, because even with heart diseases such as HCM, the disease may have a different expression and might run smoothly without affecting life expectancy [18–20]. The analysis carried out seems to confirm this thesis, and the final diagnosis would require among other things genetic testing.

Heart imaging methods such as echocardiography form an integral part of the assessment of athletes suspected of having heart disease based on medical history, physical examination or resting 12-lead ECG [4, 21]. The routine TTE at the first stage of sports screening is objectionable to many researchers, primarily for economic reasons. A number of screening protocols have been created to try to optimize the use of mass-scale TTE while minimizing time and costs [22, 23]. Wyman et al. suggested using a 5-minute TTE 2D test as a useful and relatively easily accessible screening method [24]. Other authors recommend the limited use of echocardiography for screening only in selected groups of athletes. Kinoshita et al. speculate that the inclusion of echocardiographic screening should be considered only in very tall athletes due to the more frequent occurrence of aortic dilatation in this group [25]. Until now, only a small proportion of international sports organizations have decided to use echocardiography on a wide scale. These include FIFA and its subordinate federations, as well as organizations related to motor sports, cycling and basketball (NBA) [21].

In the conducted study, it was found that performing echocardiography in all competitors allowed us to capture several significant deviations requiring further observation, which we would not have found at earlier stages of screening. One was an 18-year-old rower with a bicuspid aortic valve (BAV), without abnormal ECG findings. The next was a 28-year-old canoeist, who was characterized by an extremely thickened ventricular septum (IVS > 15 mm) and in the ECG he only met isolated voltage criteria for left ventricle hypertrophy, i.e. changes classified as adaptive (normal) – Figure 2.

It has also been shown that TTE and ECG in most cases fail to detect the same abnormalities. In the group of 57 competitors who exceeded the echocardiographic norms for athletes, as many as 52 were not selected in the ECG screening.

Based on the presented data, it seems reasonable to use echocardiography not only in pre-screening, but also in understanding heart remodelling in endurance sports.

Limitations

One of the limitations of this study is the lack of a control group composed of people who do not practise sport. However, the aim of the study was to compare the ECG and morphological parameters of the heart in two age groups of athletes subjected to the same training load. Thanks to this, it was possible to determine the impact of age and years of training on the occurrence of the observed changes and to show differences resulting from the level of training advancement.

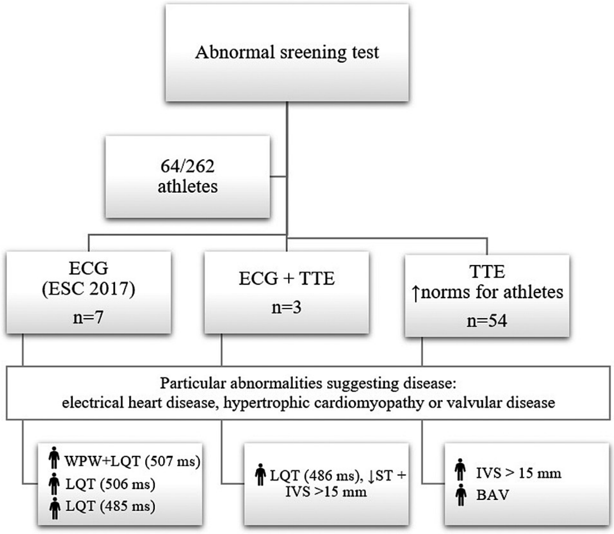

FIG. 2. The athletes with abnormal screening results. Abbreviations: BAV – bicuspid aortic valve.

Another limitation is the lack of long-term follow-up that would help assess the clinical significance of changes found in the ECG and TTE. The prospective assessment is ongoing, but this was not the purpose of the present study.

Due to the lack of a standardized measurement of blood pressure, the study did not take into account its effect on the mass and type of left ventricular hypertrophy.

CONCLUSIONS

1. Athletes practising disciplines affecting the cardiovascular system most require individualized assessment because 25% of them exceed the standards set for athletes.
2. Electrocardiographic and echocardiographic diagnostics complement each other in identifying endurance athletes requiring treatment (further verification) or special supervision. This confirms the need to perform both tests in competitive athletes.
3. Gender and training duration (in years) are the strongest independent predictors associated with the physiological adaptation of the heart to physical exertion in high-performance athletes.

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