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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

Prevalence and determinants of the early repolarisation pattern in a group of young high endurance rowers

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Abstract

Background: The prevalence and significance of the early repolarisation (ER) pattern in the general population has raised a number of questions. Even less data are available on athletes.

Aim: To determine the prevalence and determinants of ER in a group of young high endurance athletes.

Methods: We studied 117 rowers (46% women, mean age 17.5 ± 1.5 years, mean training duration 4.3 ± 1.8 years). On 12-lead electrocardiogram (ECG), we evaluated inferolateral leads for the presence of the ER pattern, defined as at least 0.1 mV elevation of the QRS-ST junction (J point) from the baseline in at least two leads. All subjects underwent detailed echocardiographic study, cardiopulmonary exercise test with evaluation of VO_2max (mean 57.1 ± 8.4 mL/kg/min), and evaluation of complete blood count and biometric parameters (fat tissue, body mass index, body surface area).

Results: We identified 35 subjects with ER in the inferior and/or lateral leads. The phenomenon was more frequent in males (n = 25, 21.36% of the overall study population) than in females (n = 10, 8.54%, p = 0.01). The training duration in both groups (with or without ER) was similar (4.4 ± 1.5 vs. 4.3 ± 1.8 years, p > 0.05). Athletes with the ER pattern had significantly higher VO_2max (58.8 ± 7.8 vs. 55.3 ± 8.2 mL/kg/min, p = 0.03), lower resting heart rate (58.7 ± 11.3 vs. 65.4 ± 11.9 bpm, p < 0.01), higher haemoglobin level (15.2 ± 0.8 vs. 14.6 ± 1.2 g/dL, p < 0.01), higher red blood cell count (5.31 ± 0.3 vs. 4.98 ± 0.4 million/µL, p = 0.04), and lower fat tissue mass (12.1 ± 4.4 vs. 14.9 ± 6.0 kg, p < 0.01). Compared with the others, the ER group was characterised by a higher left atrial area index (12.2 ± 1.3 vs. 11.5 ± 1.6 cm²/m², p = 0.01), right atrial area index (9.9 ± 1.3 vs. 9.0 ± 1.4 cm²/m², p < 0.01), and right ventricular basal diameter index (2.0 ± 0.2 vs. 1.9 ± 0.2 cm/m², p = 0.04). We found no significant differences in any other cardiac size and function parameters.

Conclusions: ER pattern in the inferior and/or lateral leads is a frequent finding in the population of young high endurance rowers. The presence of ER pattern is associated with gender and a number of parameters reflecting the general level of fitness and may be considered an electrophysiological sign of the athlete's heart. The significance of these alterations should be evaluated in prospective follow-up studies.

Key words: early repolarisation, athlete's heart, young athletes

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INTRODUCTION

Athlete's heart is the term describing physiological myocardial remodelling in response to regular, chronic, and intensive physical exercise. This encompasses both morphological and functional alterations, including electrophysiological changes [1]. Typical, most commonly noted electrocardiographic (ECG) changes associated with regular exercise training include bradycardia, first degree atrioventricular block, QRS notching

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in V1 or incomplete right bundle branch block, isolated left ventricular hypertrophy voltage criteria, and early repolarisation (ER) pattern [2–6].

For years, ER was classically defined as J point elevation with concave, upsloping ST segment followed by a tall, positive T wave in the precordial leads. This is considered a normal variant, frequently present in young healthy and fit men, resulting from enhanced vagal tone [7].

The approach to ER changed in 2008 when Haïssaguerre et al. [8] and later other authors [9] published a series of reports in which various variants of J point elevation in the inferior and/or lateral leads became associated with serious adverse events (ventricular fibrillation, sudden cardiac death) and named "early repolarisation syndrome". These publications spurred a widespread debate and initiated new research to determine prevalence and clinical importance of ER in various clinical situations [8, 9]. One study showed an association between ER and the risk of sudden death in athletes [10]. Despite these controversies, current guidelines continue to consider ER a benign pattern in athletes, not requiring further cardiac investigations [5].

In our study, we evaluated a group of young high endurance athletes who engaged in rowing, one of the most demanding sports for the cardiovascular system (high dynamic and static workload — category IIIC according to the Mitchell classification) [11]. The aim of the study was to evaluate the prevalence of ER pattern in the inferior and/or lateral leads in relation to the degree of physical fitness and detailed echocardiographic evaluation including cardiac chamber morphology and function.

METHODS

The study included 117 high endurance rowers, members of the Polish National Team (junior/youth age category) participating in national and international level competitions. All participants were Caucasians. The study was performed in April, which is a period of intense precompetition preparation during the yearly training cycle.

Initially, all athletes underwent detailed physical examination, with extended family history taking targeted at sudden cardiac death among first and second degree relatives below 45 years of age. Next, anthropometric evaluation was performed (body weight, height, adipose tissue measurement) and a venous blood sample was collected for complete blood count. Next stage included ECG and echocardiography performed at least 12 h after the last training session. The evaluation was concluded with ergospirometric exercise testing.

Anthropometric and biometric evaluation

Based on height and body mass, the Mosteller formula was used to calculate body surface area used for indexing cardiac chamber dimensions as measured by echocardiography [12].

Adipose tissue content and lean body mass were measured using a TANITA body composition analyser BC 418 (Tokyo, Japan).

Complete blood count

Complete blood count was performed using an ADVIA120 hematologic analyser (Siemens, Germany).

Electrocardiography

Resting 12-lead ECG was performed at least 12 h after the last training session using a Marquette-Hellige recorder and dedicated Cardios-Soft software (Cologne, Germany).

All tracings were analysed for the presence of ER pattern in the inferior (II, III, aVF) and/or lateral (I, aVL, V4–V6) leads, defined as ≥ 0.1 mV elevation of the J point or J wave present in at least two contiguous leads. Depending on the pattern of the QRS complex transition into the ST segment or the terminal part of QRS complex, three types of ER pattern were distinguished [13]: (1) elevated type, with J point elevation (≥ 0.1 mV) smoothly continuing as further ST segment elevation; (2) notched type, with a notch (≥ 0.1 mV) at the end of transition of the QRS complex into the ST segment; and (3) slurred type, with slurring (i.e., gradually reduced slope) of the R wave downstroke (beginning of the slope change ≥ 0.1 mV) (Fig. 1). In addition, ST segment was categorised as (a) upsloping, with ST segment elevation by ≥ 0.1 mV at 100 ms after the J point; or (b) horizontal/downsloping, with ST segment below 0.1 mV at 100 ms after the J point. Examples of ECG tracings with or without ER pattern are shown in Figure 2.

Echocardiography

Echocardiography was performed at rest in left lateral decubitus position using a Vivid 7 system (GE Vingmed Ultrasound AS, USA) and a M4S probe (1.5–4.0 MHz). Standard parasternal (long- and short axis), apical (2-, 3-, and 4-chamber), and right ventricular views were recorded. Each study included 2-dimensional imaging and tissue Doppler imaging. For strain analysis, appropriate apical and right ventricular views were recorded during three subsequent cardiac cycles while (frame rate 60–100 frames/second). All images were stored and later analysed using dedicated software (EchoPAC version 112; GE). Measurements were performed using the current guidelines [14, 15].

Left ventricular mass was calculated based on left ventricular chamber size and wall thickness in M-mode at end-diastole, using the Devereux formula [16]. Selected echocardiographic techniques are shown in Figure 3.

Ergospirometric exercise test

An ergospirometric exercise test to evaluate exercise capacity was performed using a Concept II rowing ergometer (Morrisville, USA). The test included 3-min efforts with gradually increasing workload, performed until refusal with determina-

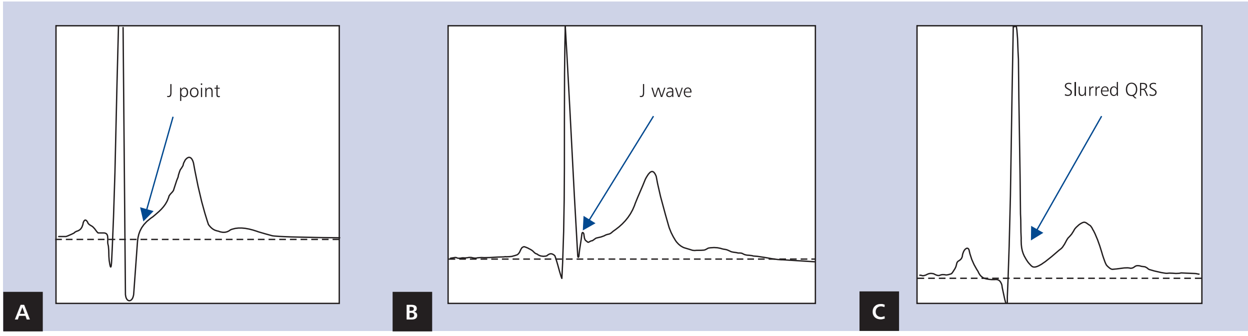

Figure 1. Morphological classification of early repolarization types; **A**. Elevated type (J point elevation); **B**. Notched type; **C**. Slurred type

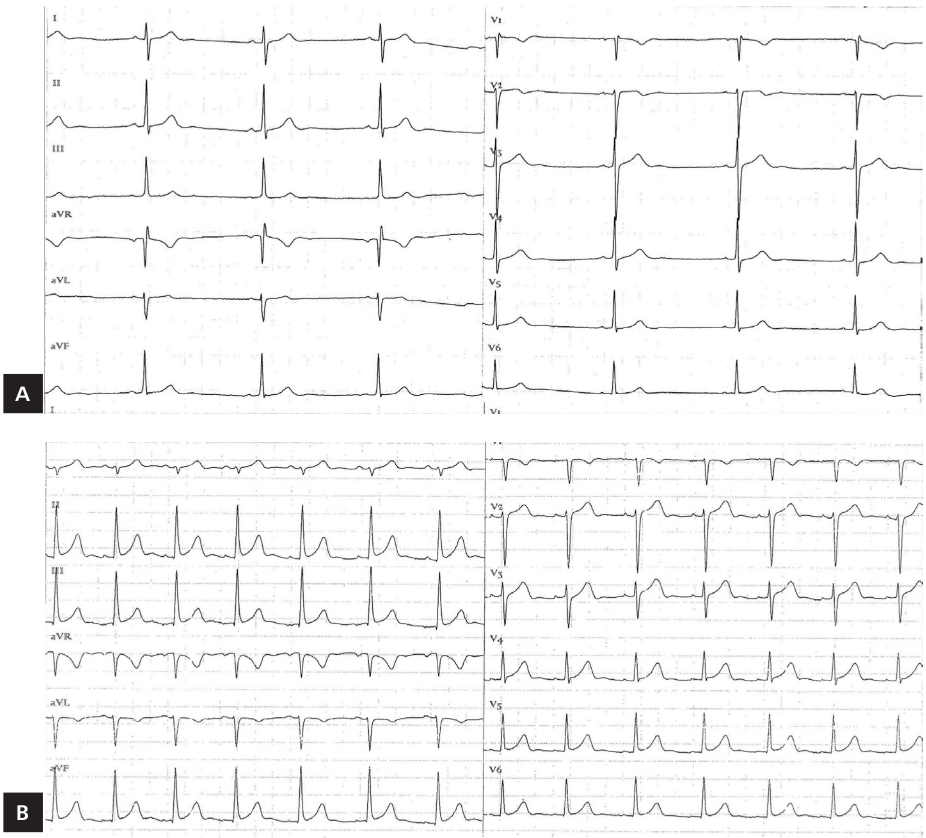

Figure 2. Examples of electrocardiograms (ECG) in two athletes; **A**. ECG tracing without the early repolarisation pattern; **B**. ECG tracing with the slurred type of the early repolarisation pattern, with changes seen in leads II, III, aVF, and V5–V6

tion of peak oxygen uptake (VO_2max). During the test, gas exchange parameters such as lung ventilation and oxygen uptake were recorded continuously (MetaLyzer 3B-R2, Cortex, Germany).

Bioethics committee

The study was approved by the bioethics committee at the Sport Institute in Warsaw, Poland. All athletes gave their written consent to participation in the study.

Statistical analysis

Statistical analysis was performed using a commercial Statistica software, version 10 (StatSoft, Tulsa, OK, USA). Data were presented as mean values ± standard deviation (SD). Normal variable distribution was tested using the Shapiro-Wilk test. Depending on variable distribution, study groups were compared using the Student t test or the Mann-Whitney U test (for quantitative variables), and 2 × 2 tables and the χ^2 test for qualitative variables. Logistic regression analysis was used

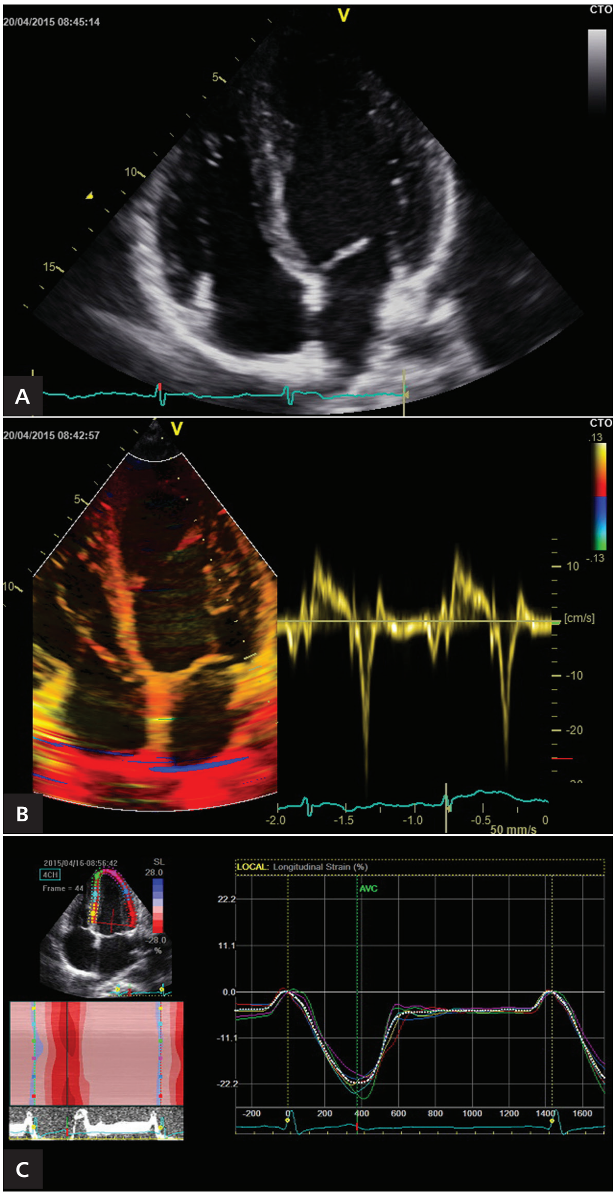

Figure 3. Echocardiography in apical four-chamber views; **A**. Cardiac chamber imaging using conventional two-dimensional echocardiography; **B**. Measurement of lateral mitral annulus velocity using tissue Doppler imaging; **C**. Measurement of left ventricular strain using acoustic speckle tracking

to calculate odds ratios (OR) with 95% confidence intervals (CI). $P < 0.05$ was considered significant. Non-significant p values in tables are denoted as NS.

RESULTS

The studied athletes were not treated for chronic diseases and had no diagnosis of and received no treatment for cardiovascular diseases. No history of a sudden death below 45 years of age was noted in any family. The mean age was 17.5 ± 1.5 years, the mean duration of training was 4.4 ± 1.8 years, and men constituted 54.7% (n = 64) of the study population. The studied athletes were characterised by a similar demographic profile, sport discipline, and training program (gender-specific). Detailed characteristics of the study group along with gender-specific data are shown in Table 1.

Electrocardiographic analysis

ECG changes fulfilling the criteria of ER pattern in the inferior and/or lateral leads were found in 35 athletes (29.9%), significantly more frequently in men (n = 25, 21.3% of the overall study population) compared to women (n = 10, 8.6%, p = 0.01). Analysis of ECG morphology revealed that the notched type was most common (n = 20, 57.1%), followed by the slurred type (n = 11, 32.4%) and the elevated type (n = 4, 11.4%).

The ER pattern was most commonly seen in both inferior and lateral leads (n = 18, 51.4%), less frequently only in inferior leads (n = 16, 45.7%), and it was limited to lateral leads in only one (2.8%) subject.

A horizontal ST segment was seen in only one subject, associated with the slurred type of ER pattern which was most evident in inferior leads.

Compared to athletes without the ER pattern, those with the ER pattern had significantly lower resting heart rate, higher Sokolov-Lyon index, lower body mass, better complete blood count parameters, higher workload during the exercise test, and higher VO_2max. Detailed data are shown in Tables 2 and 3.

Echocardiographic analysis

Among morphological parameters of cardiac chambers, athletes with the ER pattern were characterised by significantly higher (absolute and indexes) right and left atrial area and right ventricular inflow tract area (Table 4). We did not find significant differences in conventional left and right ventricular function parameters between the two groups (Table 5). Both groups were also characterised by similar global and regional longitudinal strain values for the left ventricle and the right ventricular free wall (Table 6).

Logistic regression analysis

Logistic regression analysis identified the following significant predictors of the ER pattern: male gender, better exercise capacity (as indicated by higher peak workload and VO_2max), higher Sokolov-Lyon index, lower resting heart rate, higher haemoglobin level, higher atrial area, and lower adipose tissue mass (Table 7).

DISCUSSION

Overall survival among high endurance athletes, including rowers, is higher compared to the general population [17, 18]. Despite clear benefits from participation in sports, sudden deaths among apparently healthy athletes are of large concern,

Table 1. Baseline characteristics of the study population

Parameter	Overall (n = 117)	Men (n = 63)	Women (n = 54)	P*
Age [years]	17.5 ± 1.5	17.5 ± 1.6	17.6 ± 1.4	NS
Body mass [kg]	74.5 ± 9.7	79.9 ± 7.4	68.2 ± 8	< 0.001
Height [cm]	181 ± 8.9	187.3 ± 5.5	173.6 ± 5.7	< 0.001
Body mass index [kg/m^2]	22.7 ± 2.1	22.8 ± 1.8	22.7 ± 2.4	NS
Body surface area [m^2]	2 ± 0.2	2.1 ± 0.2	1.9 ± 0.2	< 0.001
Adipose tissue content [%]	19.3 ± 7.9	13.1 ± 3.5	26.4 ± 5	< 0.001
Adipose tissue mass [kg]	14.1 ± 5.8	10.6 ± 3.4	18.2 ± 5.3	< 0.001
Lean body mass [%]	80.8 ± 7.9	87 ± 3.5	73.7 ± 5	< 0.001
Lean body mass [kg]	60.3 ± 11.2	69.4 ± 5.8	49.6 ± 4.2	< 0.001
Duration of training [years]	4.4 ± 1.8	4.4 ± 1.7	4.4 ± 1.9	NS
Duration of ergospirometric exercise test [min]	15.8 ± 2.6	17.3 ± 2.4	14.1 ± 1.6	< 0.001
Workload [W]	311 ± 61.2	358.1 ± 37.5	256.1 ± 28.9	< 0.001
Workload/body mass [W/kg]	4.2 ± 0.6	4.6 ± 0.5	3.8 ± 0.5	< 0.001
VO_2max [L/min]	4.3 ± 1	5 ± 0.7	3.4 ± 0.4	< 0.001
VO_2max/body mass [mL/kg/min]	56.4 ± 8.3	62.1 ± 5.9	49.8 ± 5.2	< 0.001
Peak heart rate [bpm]	195.2 ± 8.4	195.6 ± 8.6	194.8 ± 8.3	NS
Resting heart rate [bpm]	63.5 ± 12	61.8 ± 8.6	65.4 ± 13.2	NS

*Statistical significance for the comparison of men vs. women; VO_2max — peak oxygen uptake

Table 2. Comparison of athletes with or without the early repolarisation pattern (ERP) in regard to selected electrocardiographic and complete blood count parameters

Parameter	ERP (+) N = 35	ERP (–) N = 82	P
Resting heart rate [bpm]	**58.7 ± 11.3**	**65.5 ± 12.0**	**0.005**
PR interval [ms]	154.7 ± 24.8	151.6 ± 21.6	NS
QTc [ms]	391.9 ± 25.1	402.8 ± 32.1	NS
S_{V1} + $R_{V5/6}$ [mm]	**29.6 ± 8.7**	**25.5 ± 7.5**	**0.01**
White blood cell count [×10^3/µL]	6.5 ± 1.1	6.3 ± 1.3	NS
Haemoglobin [mg/dL]	**152.4 ± 8.7**	**146.0 ± 12.2**	**0.006**
Red blood cell count [×10^6/µL]	**5.1 ± 0.3**	**5.0 ± 0.4**	**0.04**
Haematocrit [%]	**43.7 ± 2.2**	**42.1 ± 3.0**	**0.006**
Mean corpuscular volume [fL]	85.1 ± 3.4	84.5 ± 3.0	NS
Mean corpuscular haemoglobin [pg]	29.7 ± 1.2	29.3 ± 1.2	NS
Mean corpuscular haemoglobin concentration [g/L]	348.9 ± 7.4	346.9 ± 7.4	NS
Platelet count [×10^3/µL]	265.1 ± 64.6	277.4 ± 56.4	NS

also for the general public. The incidence of death among young athletes is 9.8/1,000,000 persons/year and is several times higher compared to young subjects not participating in sports (2.2/1,000,000 persons/year) [19]. Methods that allow effective identification of subjects at risk are the main focus of screening. The value and types of investigations useful for screening in athletes are a subject of ongoing debate. Initial evaluation, in addition to history and screening, may include ECG and less frequently echocardiography. Screening tests and their utility in competitive athletes were discussed by Leischik et al. [20, 21]. Following studies in athletes, a recent study also evaluated the usefulness of screening ECG in the general population [22].

In the present study, we used a number of diagnostic tests (including ECG, echocardiography, and ergospirometric exercise test) to perform a detailed evaluation of young

Table 3. Comparison of athletes with or without the early repolarisation pattern (ERP) in regard to selected anthropometric and ergospirometric exercise test parameters

Parameter	ERP (+) N = 35	ERP (–) N = 82	P
Age [years]	17.7 ± 1.4	17.4 ± 1.5	NS
Height [cm]	183.3 ± 9.0	179.9 ± 8.6	NS
Body mass [kg]	75.7 ± 8.8	73.9 ± 10.0	NS
Body mass index [kg/m^2]	22.5 ± 1.8	22.8 ± 2.2	NS
Adipose tissue [kg]	**12.1 ± 4.4**	**14.9 ± 6.1**	**0.02**
Lean body mass [kg]	62.9 ± 10.8	59.1 ± 11.1	NS
Duration of training [years]	4.4 ± 1.5	4.3 ± 1.9	NS
Duration of ergospirometric exercise test	16.0 ± 2.6	15.8 ± 2.6	NS
Workload [W]	**331.3 ± 55.9**	**302.2 ± 61.5**	**0.02**
Workload/body mass [W/kg]	**4.4 ± 0.5**	**4.1 ± 0.6**	**0.01**
VO_2max [L/min]	4.5 ± 0.9	4.1 ± 0.9	NS
VO_2max/body mass [mL/kg/min]	**58.9 ± 7.9**	**55.3 ± 8.2**	**0.03**

VO_2max — peak oxygen uptake

Table 4. Comparison of athletes with or without the early repolarisation pattern (ERP) in regard to cardiac chamber morphologic parameters

Parameter	ERP (+) N = 35	ERP (–) N = 82	P
Left ventricular diastolic diameter [cm]	5.10 ± 0.4	4.99 ± 0.4	NS
Interventricular septum thickness — at diastole [cm]	1.09 ± 0.1	1.07 ± 0.1	NS
Posterior wall thickness — at diastole [cm]	1.08 ± 0.1	1.03 ± 0.1	NS
Left ventricular mass [g]	259.7 ± 55.4	239.9 ± 53.8	NS
Left atrial diameter [cm]	3.75 ± 0.5	3.61 ± 0.4	NS
Right ventricular outflow tract — proximal [cm]	2.97 ± 0.3	2.88 ± 0.3	NS
Right ventricular outflow tract — distal [cm]	3.13 ± 0.5	2.99 ± 0.5	NS
Left atrial area [cm^2]	**23.99 ± 3.3**	**22.00 ± 3.2**	**0.003**
Right atrial area [cm^2]	**19.51 ± 3.1**	**17.39 ± 2.8**	**< 0.001**
Right ventricle — base [cm]	**3.93 ± 0.5**	**3.67 ± 0.4**	**0.004**
Right ventricle — mid-level [cm]	**3.05 ± 0.4**	**2.82 ± 0.5**	**0.01**
Right ventricle — long-axis [cm]	8.11 ± 0.7	7.83 ± 0.8	NS
Left ventricular diameter/BSA [cm/m^2]	2.61 ± 0.2	2.61 ± 0.2	NS
Left atrial diameter/BSA [cm/m^2]	1.91 ± 0.2	1.89 ± 0.2	NS
Right ventricular outflow tract — proximal/BSA [cm/m^2]	1.52 ± 0.1	1.51 ± 0.1	NS
Right ventricular outflow tract — distal/BSA [cm/m^2]	1.59 ± 0.3	1.56 ± 0.2	NS
Left atrial area/BSA [cm^2/m^2]	**12.22 ± 1.3**	**11.49 ± 1.6**	**0.01**
Right atrial area/BSA [cm^2/m^2]	**9.93 ± 1.3**	**9.07 ± 1.4**	**0.002**
Right ventricle — base/BSA [cm/m^2]	**2.00 ± 0.2**	**1.92 ± 0.2**	**0.04**
Right ventricle — mid-level/BSA [cm/m^2]	1.56 ± 0.2	1.48 ± 0.3	NS
Right ventricle — long-axis/BSA [cm/m^2]	4.14 ± 0.4	4.10 ± 0.4	NS

BSA — body surface area

Table 5. Comparison of athletes with or without the early repolarization pattern (ERP) in regard to selected functional parameters

Parameter	ERP (+) N = 35	ERP (–) N = 82	P
Pulmonary flow acceleration time [ms]	149.5 ± 15.6	149.8 ± 17.9	NS
Tricuspid annular plane systolic excursion [mm]	24.0 ± 3.3	23.6 ± 2.9	NS
MVivs S' [cm/s]	9.7 ± 1.5	9.7 ± 1.4	NS
MVlat S' [cm/s]	12.5 ± 1.9	12.3 ± 2.6	NS
MVivs E/e'	5.8 ± 1.0	5.9 ± 1.2	NS
MVlat E/e'	4.4 ± 0.8	4.3 ± 0.8	NS
Systolic tricuspid annular velocity [cm/s]	14.3 ± 2.0	14.5 ± 2.4	NS

MVivs S' — systolic septal mitral annular velocity; MVlat S' — systolic lateral mitral annular velocity; MVivs E/e' — early diastolic mitral inflow velocity to early diastolic septal mitral annular velocity ratio; MVlat E/e' — early diastolic mitral inflow velocity to early diastolic lateral mitral annular velocity ratio

Table 6. Comparison of athletes with or without the early repolarisation pattern (ERP) in regard to strain

Parameter	ERP (+) N = 35	ERP (–) N = 82	P
Longitudinal peak systolic strain of the left ventricle			
Basal segments [%]	–19.1 ± 1.7	–19.7 ± 2.1	NS
Middle segments [%]	–20.5 ± 1.7	–20.8 ± 2.0	NS
Apical segments [%]	–20.4 ± 2.9	–20.0 ± 3.2	NS
Global value [%]	–20.2 ± 1.7	–20.5 ± 2.0	NS
Longitudinal peak systolic strain of the right ventricle			
Basal segments [%]	–25.9 ± 4.8	–25.8 ± 4.3	NS
Middle segments [%]	–28.9 ± 3.2	–29.9 ± 3.6	NS
Apical segments [%]	–26.0 ± 3.4	–27.5 ± 4.4	NS
Global value [%]	–27.0 ± 2.6	–27.8 ± 3.2	NS

Table 7. Logistic regression analysis — predictors of the early repolarisation pattern (ERP)

Parameter	ERP		P
	Odds ratio	95% CI	
Gender — men vs. women	2.89	1.22–6.84	0.01
Workload/body mass [W/kg]	2.45	1.17–5.15	0.01
VO_2max/body mass — per each 10 mL/kg/min	1.71	1.02–2.48	0.007
Sokolov-Lyon index — per 1 mV	1.89	1.13–3.18	0.01
Resting heart rate — per reduction by 10 bpm	1.68	1.14–2.48	0.007
Haemoglobin level — per increase by 1 g/dL	1.66	1.14–2.43	0.007
Right atrial area index — per increase by 1 cm^2/m^2	1.61	1.16–2.21	0.002
Left atrial area index — per increase by 1 cm^2/m^2	1.36	1.03–1.78	0.02
Adipose tissue — per decrease by 1 kg	1.1	1.02–1.17	0.02

CI — confidence interval; VO_2max — peak oxygen uptake

athletes. Our study provides valuable data on the prevalence and morphological characteristics of ER in the inferior and/or lateral leads in high endurance athletes. A clear advantage of our work is the uniform nature of the study population consisting of young, well-trained rowers who did not differ in regard to race, sport discipline, age group, training program (gender-specific), and the timing of our evaluation within the annual training cycle. Importantly, rowing is one of the most demanding sports for the cardiovascular system and may be expected to have a clearly evident effect on cardiac remodelling.

In our study, we found that the ER pattern in the inferior and/or lateral leads is a frequent phenomenon already in young athletes. The presence of the ER pattern was clearly related to parameters reflecting the degree of fitness and physiological adaptation to strenuous exercise.

Detailed echocardiographic evaluation showed no significant differences in structural and functional parameters reflecting cardiac function. Increased atrial chamber size and increased basal right ventricular diameter are a result of physiological adaptation and response to the nature of cardiac load in athletes engaged in disciplines where one of the components of the exercise is maximum dynamic load. In these athletes, exercise is associated with a large increase in cardiac output, resulting in volume overload and subsequent increase in cardiac chamber size and volume [23]. We did not find differences in left ventricular myocardial thickness and mass, which might be expected when comparing athletes with and without the ER pattern. Similar results were reported by Noseworthy et al. [13] who concluded that the presence of the ER pattern is a result of cardiac adaptation to exercise that develops in parallel to and not as a consequence of structural cardiac remodelling in athletes.

The prevalence of the ER pattern in the general population reported in previous studies varied widely, from about 1% to 31%. These large differences may be due to a number of factors (age, gender, physical activity), including varying criteria used to define the ER pattern [24].

In our study population, the prevalence of ER pattern was 29.9%, which closely corresponds to the results reported by other authors and confirms common occurrence of such ECG alterations in high endurance athletes [2, 13, 25–27]. Despite nearly identical overall prevalence of the ER pattern, large differences in the rates of these alterations in specific leads were noted between various studies. Depending on the study, the prevalence of an isolated ER pattern in the inferior leads ranged from about 6% to 40% [13, 25]. In our study, the ER pattern in the inferior leads was present in 45% of all athletes with the ER pattern. Compared to other studies, we observed a relatively frequent (51.4% of cases) presence of the ER pattern in both inferior and lateral leads. It seems that large differences in ER pattern presentation in various leads may be related to the current degree of fitness. This concept is supported by the study by Noseworthy et al. [13] who found a twofold increase in the prevalence of the ER pattern in the inferior leads following 90 days of training in one subgroup of the studied population. Our study population consisted of athletes evaluated during the period of intense precompetition training. The observed differences in the rates of the ER pattern between published studies may also be related to the differences in the characteristics of the studied populations (race, sports discipline).

In a study that specifically evaluated rowers, the prevalence of the ER pattern in the inferior and/or lateral leads was 25%, similarly to our findings (29.2%). In contrast to our study, in which the ER pattern was significantly more frequent in men, Wasfy et al. [27] did not observe such differences. The reasons for these discrepancies in regard to gender-specific prevalence are difficult to interpret, as many details of the general characteristics of the population studied by Wasfy et al. [27] were not reported (e.g., no data on training duration, the degree of training workload, fitness parameters).

Our study provided additional information on the prevalence of the ER pattern in relation to the degree of fitness evaluated objectively by the ergospirometric exercise testing. We found a clear relation between the ER pattern and better fitness, and strong predictors of the ER pattern included VO_2max and maximum workload during the exercise test.

Our findings are in concordance with the generally accepted notion that various forms of the ER pattern in the inferior and/or lateral leads should be considered a normal variant which usually does not require further investigations [5]. This position is also supported by the results of long-term follow-up studies [26].

On the other hand, studies showed a higher mortality risk in subjects with the ER pattern in specific clinical scenarios (heart failure, ischaemic heart disease) [28, 29] in the general population [24] and, which might indeed be concerning, in high endurance athletes [10].

Recent studies attempted to define potentially dangerous ER pattern variants, dubbed “malignant early repolarisation syndrome”. It was shown that multiple risk factors are associated with adverse outcomes (malignant arrhythmia, sudden cardiac death) in subjects with ER, including (in the order of decreasing importance) a history of cardiac arrest and documented ventricular fibrillation, a positive family history of sudden cardiac death, transient changes of J wave amplitude, short-coupled premature ventricular beats, and concomitant electrophysiological conditions such as Brugada syndrome, short QT syndrome, J point elevation ≥ 2 mm in the inferior leads, concomitant presence of the ER pattern in the inferior and lateral leads or many leads, horizontal or downward sloping ST segment [30, 31].

In our study, we did not identify a combination of these adverse prognostic factors in any of the athletes. However, concomitant presence of the ER pattern in the inferior and lateral leads was a relatively frequent finding. However, this form of the ER (similarly to the previously reported more frequent prevalence of the ER pattern in the inferior leads) might have resulted from the nature and severity of the effort undertaken by the studied athletes. In one athlete, horizontal ST segment combined with the slurred type of the ER pattern was identified. Apart from this “abnormality”, clinical examination and investigations did not reveal any other abnormal findings, and VO_2max in this athlete was 57 mL/min/kg body mass.

It has been postulated that the term “early repolarisation syndrome”, with its rather negative connotations, should be used only in the clinical context of adverse outcomes, limited to subjects with the typical ECG pattern of ER and a history of cardiac arrest, documented ventricular fibrillation/polymorphic ventricular tachycardia, or an established genetic mutation which may predispose to such adverse events [31, 32]. Our findings clearly indicate the need for a precise distinction between benign adaptive changes and potentially arrhythmogenic and life-threatening electrophysiological alterations.

Limitations of the study

One study limitation (from a population perspective) is a relatively low number of athletes studied (although very high in terms of studies performed in high endurance athletes), which may be of some importance for ECG analysis. It should be noted, however, that the study was performed in a homogenous group of athletes who underwent comprehensive diagnostic testing (echocardiography, ergospirometric exercise test) on a single day, in a defined order, and, importantly, during similar phase of the training cycle. Such study design allowed evaluation of direct relationships between the degree of fitness, echocardiographic findings, and repolarisation abnormalities. This is of major importance, particularly when performing ECG and echocardiographic evaluation of the athlete's heart which may be significantly affected by the phase of the training cycle or even a short period of detraining. Another obvious limitation if the lack of long-term follow-up which would allow definitive assessment of the clinical significance of the observed ECG alterations. Taking into account the incidental nature of life-threatening arrhythmic events among young healthy athletes (2–4/100,000/year) and rare occurrence of potentially malignant ER forms (< 1% in the studied population), such prospective evaluation would require many years of follow-up of a large population.

CONCLUSIONS

1. Early repolarisation pattern in the inferior and/or lateral leads is a frequent finding in the population of young high endurance rowers.
2. The presence of ER pattern in rowers is associated with gender and a number of parameters reflecting the general level of fitness.
3. The benign form of the ER pattern in the inferior and/or lateral leads may be considered a manifestation of physiological adaptation to exercise, i.e. an electrophysiological a sign of the athlete's heart.
4. Athletes with the ER pattern should be subjected to long-term follow-up to determine the significance of the observed alterations.

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Ocena zmian o charakterze wczesnej repolaryzacji w grupie młodych sportowców wyczynowych trenujących wioślarstwo

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Streszczenie

Wstęp: Znaczenie prognostyczne występowania wczesnej repolaryzacji (ER) w odprowadzeniach znad ściany dolnej i/lub bocznej ciągle pozostaje tematem aktywnych badań. Jedną z grup szczególnego zainteresowania pozostają sportowcy wyczynowi.

Cel: Celem pracy było stwierdzenie częstości występowania oraz znalezienie czynników predykcyjnych związanych z obecnością ER w grupie młodych sportowców wyczynowych uprawiających wioślarstwo, które jest jedną z dyscyplin sportowych najbardziej obciążających układ sercowo-naczyniowy.

Metody: Do badania włączono 117 sportowców wyczynowych — wioślarzy (mężczyźni: 54%, średni wiek: 17,5 ± 1,5 roku, średni okres trenowania: 4,4 ± 1,8 roku). Na podstawie wyników 12-odprowadzeniowego badania elektrokardiograficznego (EKG) zidentyfikowano osoby z cechami ER w odprowadzeniach znad ściany dolnej i/lub bocznej. ER definiowano jako uniesienie punktu J/załamka J ≥ 1 mV obecne w co najmniej dwóch sąsiednich odprowadzeniach. U wszystkich wykonano szczegółowe badanie echokardiograficzne, badanie spiroergometryczne z oceną VO_2max (średnia wartość: 57,1 ± 8,4 ml/kg/min), oceniano morfologię krwi żylnej i wybrane parametry biometryczne (zawartość tkanki tłuszczowej, wskaźnik masy ciała, pole powierzchni ciała).

Wyniki: W badanej grupie zidentyfikowano 35 (29,9%) osób z cechami ER obecnymi w odprowadzeniach znad ściany dolnej i/lub bocznej. ER częściej występowało u mężczyzn (25; 21,4%) niż u kobiet (10; 8,5%; p = 0,01). Średni okres trenowania w obu grupach (ER *vs*. pozostali) był podobny (4,4 ± 1,5 *vs*. 4,3 ± 1,8 roku; p > 0,05). W grupie osób z ER, w porównaniu z pozostałymi badanymi, stwierdzono następujące zmienne, które były istotne statystycznie: wyższe wartości VO_2max (58,8 ± 7,8 *vs*. 55,3 ± 8,2 ml/kg/min; p = 0,03), niższa spoczynkowa częstość rytmu serca (58,7 ± 11,3 *vs*. 65,4 ± 11,9 uderzeń na minutę; p < 0,01), wyższe stężenie hemoglobiny (15,2 ± 0,8 *vs*. 14,6 ± 1,2 g/dl; p < 0,01), większa liczba czerwonych krwinek (5,31 ± 0,3 *vs*. 4,98 ± 0,4 mln komórek/μl; p = 0,04) oraz niższa oszacowana masa tkanki tłuszczowej (12,1 ± 4,4 *vs*. 14,9 ± 6,0 kg; p < 0,01). Porównując osoby z ER z pozostałą grupą badanych, wyniki echokardiografii, poza większym indeksowanym wymiarem prawego i lewego przedsionka oraz większym podstawnym wymiarem prawej komory, nie wykazały różnic w zakresie pozostałych ocenianych parametrów.

Wnioski: 1. Wczesna repolaryzacja w odprowadzeniach znad ściany dolnej i/lub bocznej występuje często w spoczynkowym EKG w grupie sportowców wyczynowych. 2. Obecność wczesnej repolaryzacji wiąże się z płcią i wieloma parametrami odzwierciedlającymi ogólny poziom wytrenowania, co przemawia za fizjologicznym charakterem zmian i może być uznane za elektrofizjologiczny wykładnik tzw. „serca sportowca".

Słowa kluczowe: serce sportowca, wczesna repolaryzacja, młodzi sportowcy

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