International Journal of Biomedicine 9(4) (2019) 297-299
http://dx.doi.org/10.21103/Article9(4)_OA4

INTERNATIONAL JOURNAL OF BIOMEDICINE

ORIGINAL ARTICLE

Cardiology

The Electrical Activity of the Heart during Ventricular Repolarization and Types of the Remodeling of the Athlete`s Heart

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Abstract

The aim of this work was to investigate the electrical activity of the athletes' hearts with different types of the left ventricular remodeling, as well as a control group of untrained people, by the body surface potential mapping before and immediately after exercising. The study of the heart's electric field in athletes of the same sex, age and sport qualification, but different sport disciplines, showed that the reaction of the heart to physical activity is reflected in different changes of the amplitude-temporal characteristics of the extremes on the body's surface in athletes with eccentric and concentric myocardial remodeling. (**International Journal of Biomedicine. 2019;9(4):297-299.**)

Key Words: ventricular repolarization • ventricular remodeling • electrical activity • body surface potential mapping

Abbreviations

ARD, aortic root diameter; **BSPM**, body surface potential mapping; **HR**, heart rate; **LVEDD**, left ventricular *(***LV***)* end-diastolic diameter; **LVM**, LV mass; **LVMI**, LV mass index; **PWT**, posterior wall thickness; **LVRWT***,* LV relative wall thickness; **LVEF**, LV ejection fraction; **SWT**, septal wall thickness; **VR**, ventricular repolarization.

Introduction

The specificity of sports specialization[1] defines the type of "sports heart" remodeling.[2,3] In endurance athletes, an increase of myocardial preload leads to an increase in the size of the heart and ventricular cavities and an increase in the stroke volume, and forms the eccentric hypertrophy of the left ventricle. In strength athletes an increase of myocardial afterload leads to an increase in the mass of the LV myocardium without dilatation of the cavities, and forms the concentric myocardial hypertrophy.[3,4] Structural and functional cardiac remodeling leads to electrophysiological remodeling.[5] Using standard ECG on an athlete`s heart during VR, the general particularities are: J-point elevation, ST segment elevation/depression, tall and peaked T-wave, and isoelectric, biphasic or inverted T-waves.[6,7] When an athlete performs physical exercise, these ECG features disappear, which confirms their functional, rather than structural, origin.[8] BSPM method, known as a noninvasive, multichannel, synchronous recording of electrical potentials of the heart on the thoracic surface from multiple unipolar leads, is a more informative method for studying the functional state of the heart, which makes it possible to obtain more data on the electrical processes in the myocardium than with the standard electrocardiography.[9,10]

The aim of this work was to investigate the electrical activity of the athletes' hearts with different types of the LV remodeling, as well as a control group of untrained people, by the BSPM before and immediately after exercising.

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Materials and Methods

The 25 athletes were examined by the methods of echo- and electrocardiography. All athletes were male with the sports qualifications of candidates for Master of Sports of Russia and Master of Sports of Russia. Three sporting disciplines predominantly made up the study group: swimming (n=10; age of 19.5±0.5 years; weight of 76.0±9.5 kg; height of 179±6 cm), weightlifting (n=8; age of 19.5±1.5 years; weight of 77.6±8.3 kg; height of 174.3±6.0 cm) and cross-country skiing (n=7; age of 18.9±1.1 years; weight of 76±4.0 kg; height of 178.1±3.2 cm). The control group comprised 9 healthy adult volunteers (age of 19,7±0,8 years; weight of 70,8±6,4 kg; height of 176,9±4,9 cm).

Echocardiography

Two-dimensional EchoCG was perfumed with the subjects resting in a left lateral decubitus position using LOGIC Pro (GE, USA) with a 5MHz transducer. The heart images obtained in M- and B- modes in the standard parasternal long-axis and four chambers positions, according to guidelines of the American Society of Echocardiography,(11) were used to measure LVEDV, SWT, PWT, and ARD. The Devereux formula (1986) was used to calculate LVM (g). We calculated LVMI (g/m^2) as the ratio of LVM to body surface area, LVRWT as the ratio of double PWT to LVEDV, and LVEF using the Teichholz method.

Multichannel electrocardiography

The heart's electrical activity in the young men was studied using multichannel ECG during VR. BSPM with 64 unipolar leads covering the thorax was performed; Standard lead II was used as the reference.(9) The electrodes were located evenly on the ventral and dorsal surfaces of the torso with a 3-5cm distance between them. The electrodes were attached to 8 flexible strips, each containing 8 electrodes. BSPM was recorded at rest and during the recovery period after submaximal physical exercise. Using a bicycle ergometer (KETTLER, Germany), subjects performed two workloads, each lasting 5 minutes. The first (moderate) workload corresponded to 1.5 W/kg body weight. The second workload was submaximal and was calculated according HR at the fifth minute of the first workload. During the second workload, HR of the subjects reached 170 bpm. After each load, there was a 3-minute recovery period.

We analyzed the amplitude characteristics of the positive and negative extremes (the amplitude of the maximum and the minimum, respectively) and the time they reached the maximum amplitudes at the period of VR (the maximum time and the minimum time, respectively).

The study was conducted in accordance with ethical principles of the WMA Declaration of Helsinki (1964, ed. 2013) and approved by the KSC UB RAS Ethics Committee. Written informed consent was obtained from all participants.

Statistical analysis was performed using the statistical software SPSS version 22.0. The normality of distribution of continuous variables was tested by the Shapiro–Wilk test. Variables were presented as mean+SD. For data with normal distribution, inter-group comparisons were performed using Student's t-test. Differences of continuous variables departing from the normal distribution were tested by the Mann-Whitney U-test. A probability value of P<0.05 was considered statistically significant.

Results

According to recommendations(11) as the result of an echocardiographic study, two types of LV remodeling were revealed in the subjects: eccentric (cross-country skiers and swimmers) and concentric (weightlifters).

Indicators of LVM, LVMI, and LVRWT were as follows: in skiers— 217.3±31.6 g, 112.7±15.0 g/m^2, and 0.35±0.01; in swimmers—192.6±1.3 g, 100.0±9.8 g/m^2; and 0.37±0.02; in weightlifters—153.4±40.7 g, 87.4±19.3 g/m^2, and 0.33±0.01, respectively.

In comparison with the untrained people, significant differences were revealed in the indicators of LVM and LVMI for skiers and swimmers, and in the indicator of LVRWT for weightlifters. A statistically significant difference was revealed between skiers and weightlifters in the indicators of LVM and LVMI.

The amplitude of positive extremum in weightlifters and untrained people increased during the recovery period (2, 3 min), in swimmers and skiers at the cessation of exercise (1 min recovery). The maximal increase in positive extremum was found in skiers.

The amplitude of negative extremum was increased (vs. baseline) in all subjects at the cessation of exercise, and decreased during 3 minutes of the recovery period until it reached the initial value (excluding untrained people).

In all subjects, the time required to reach the maximal values for positive and negative extremes decreased significantly in comparison with initial values after exercise. The maximal decrease was obtained in swimmers (by 44% for t_{min} and 40% for t_{max}), and minimal in weightlifters (by 39% for t_{min} and t_{max}) (Table 1).

According to anthropometric data, the compared groups were similar. Studies on humans and animals have shown that the chest size, fat tissue and size of the pectoral muscles have a slight effect on the heart's electrical activity on the body surface.(9,12) Therefore, the difference in the ratio of muscle, fat and bone tissue among athletes of different sports(13) can be neglected, and the revealed differences in the BSPM characteristics are due to the influence of the type of myocardial remodeling. During physical workload, the indicators of HR and stroke volume increase rapidly; as a result, the strength of myocardial contraction increases, and these changes are much greater in athletes than in untrained people.

In comparison with weightlifters, the cross-country skiers and the swimmers have a larger heart size and volume of the left ventricle, but have less thickness of the interventricular septum and posterior wall of the left ventricle. Earlier, we showed that in cross-country skiers and weightlifters the duration of the ventricular depolarization period of the heart was the same, but the duration of the different phases of depolarization was different. These differences indicate a difference in the heart's electrical activity in athletes with eccentric and concentric types of myocardial remodeling.

According to the BSPM results of this study, during the period of VR, the temporal characteristics of the extremes after exercise change maximally in endurance athletes (swimmers and skiers), and minimally in strength athletes (weightlifters). As a result of a static training in weightlifting, a ventricular pressure overload leads to a thickening of the heart wall,(15) and the diameter of the myofibrils in the cardiomyocytes increases without an increase in their number.(16)) In dynamic training in cross-country skiing, overload of ventricles by volume leads to lengthening of cardiomyocytes. According to experimental data on animals with pathological hypertrophy of the left ventricular, the t_{max} extremes increase during VR.(17) In our study, there were no differences in the indicators of the maximum time and the minimum time between athletes with eccentric and concentric myocardial remodeling at baseline, which confirms the physiological origin of wall thickening in weightlifters.

Table 1.

The amplitude-temporal characteristics of the extremes in subjects during rest and recovery period after submaximal workload

Extremes	Subjects	Baseline	Recovery period after physical workload		
			1 min	2 min	3 min
max, mV	untrained people	0.86±0.05	0.86±0.25	1.05±0.35	0.98±0.36
	cross-country skiers	$0.99±0.12^{\#}$	1.07±0.41	0.82±0.38	0.88±0.28
	swimmers	$0.76±0.17^{\circ}$	0.94±0.10	0.93±0.10	$0.74±0.09^{*}$
	weightlifters	0.91±0.16	0.87±0.31	0.87±0.40	0.97±0.30
min, mV	untrained people	0.34±0.04	0.40±0.09	0.39±0.12	$0.42±0.03^{*}$
	cross-country skiers	0.35±0.08	$0.50±0.09^{*}$	$0.53±0.16^{*}$	$0.30±0.06^{\#}$
	swimmers	0.36±12	0.39±0.10	0.41±0.10	0.33±0.10
	weightlifters	0.33±0.11	0.44±0.24	0.39±0.13	0.32±0.14
t_{max}, ms	untrained people	220±16	$136±14^{*}$	149±18*	$161±20^{*}$
	cross-country skiers	256±54	$166±5^{*\#}$	$197±17^{\#}$	$228±37^{\#}$
	swimmers	250±32	$150±14^{*\circ}$	$173±26^{*}$	$197±35^{*}$
	weightlifters	225±37	$156±27^{*}$	$160±44^{*}$	175±57
t_{min}, ms	untrained people	234±14	$141±14^{*}$	$154±19^{*}$	$156±18^{*}$
	cross-country skiers	$272±39^{\#}$	$165±7*^{\#}$	$198±15^{*\#}$	$199±47^{*}$
	swimmers	$263±20^{\wedge}$	$147±16^{*}$	$160±20^{*}$	$207±33^{*\wedge}$
	weightlifters	226±38	$156±17^{*}$	$175±22^{*}$	190±39

P<0.05 in comparison to: **- baseline;* $^{\#}$*- between cross-country skiers and untrained people;* $^{\circ}$*- between swimmers and cross-country skiers;* $^{\wedge}$*- between swimmers and untrained people*

Thus, the study of the heart's electric field in athletes of the same sex, age and sport qualification, but different sport disciplines, showed that the reaction of the heart to physical activity is reflected in different changes of the amplitude-temporal characteristics of the extremes on the body's surface in athletes with eccentric and concentric myocardial remodeling.

Sources of Funding

The reported study was supported by KSC UB RAS according to Research Project AAAA-A18-118012390260-9 and by UB RAS according to the Complex Program AAAA-A18-118012390269-2.

Competing Interests

The authors declare that they have no competing interests.

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