Changes in Systolic and Diastolic Functions of the Left Ventricle and Endothelium Function against the Background of Electric Stimulation in Athletes

G. A. Khairetdinova, Yu. N. Fedulaev*, V. V. Ar'kov, S. S. Pertsov, and O. N. Andreyeva*

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Against the background of 10 procedures of electric stimulation of the quadriceps muscle of the thigh performed in 72 athletes we observed a significant increase in volume parameters of the left-ventricular systolic function and increase in diastolic function in a group of athletes during the recovery period. Significant increase in endothelium-dependent values was noted in both groups during electric myostimulation; it directly correlated with all metric and integral echocardiography parameters in main group.

Key Words: *electric myostimulation; systolic and diastolic functions of left ventricle; endothelium-dependent reaction*

Maintenance of adequate central hemodynamics is a multicomponent process determined by force and volume of cardiac output, sufficient myocardium relaxation during the diastole, and readiness of elastic arteries for reception of stroke and minute volumes [1,2,3]. Significant and differently directed fluctuations for individual component of this process are known within non-pathological range [2,3]. The use for electric myostimulation (EMS) in athletes is generally limited to investigations of peripheral hemodynamics using rheographical methods with subsequent probabilistic assessment of central hemodynamics, which does not provide details and ratios for the main components of central circulation [1,4,5]. There are no publications for complex central hemodynamics assessment in athletes using modern echocardiography and dopplercardiometry methods against the background of EMS.

The objective of this study was to assess in dynamics of parameters characterizing systolic and diastolic functions of the left ventricle (LV) and endothelium during EMS.

Institute of Physical Culture and Sport; *N. N. Pirogov Russian State Medical University, Moscow, Russia. ***Address for correspondence:*** sportcardio@mail.ru. G. A. Khairetdinova

MATERIALS AND METHODS

Seventy-two athletes specialized in ski race, mean age of 25.3±4.8 years, participated in this study. The main group comprised 37 athletes (20 males and 17 females, mean age 24.7±4.5 years) at recovery stage of training. Control group included 35 athletes (21 males and 14 females, mean age 25.0±4.3 years) diagnosed with patellofemoral arthrosis, which had no trainings during last two months. Electrostimulation of the quadriceps muscle of the thigh was performed for 10 days with 2-day break in the middle. We used Kots current (duration 10 sec, pause 50 sec, frequency modulation 50 Hz, duration of trapezoid-shape impulse 10 msec; carrier frequency – 2500 Hz). Initial echocardiography parameters were assessed on days 5 and 10: parameters of systolic (IVST: interventricular septum thickness, LVPWT: left ventricular posterior wall thickness, EDS: end-diastolic size, ESS: end-systolic size, EDV: end-diastolic volume, ESV: end-systolic volume, EF: ejection fraction) and diastolic functions of the LV (E/A: ratio between early and late filling periods, IVRT: isovolumic relaxation time, DT: deceleration time in early diastole) and endothelium-

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dependent reactions (EDR) of the brachial artery in response to reactive hyperemia.

The data were statistically processed using Biostatistica 4.03 software. Quantitative parameters are presented as *M*±*SD*, while qualitative parameters presented as a fraction of the set sample. Statistical significance was considered to be confirmed when $p<0.05$.

RESULTS

Baseline metric and volume parameters of LV in both groups were similar, except ESV, which was significantly higher in main group than in control group by 21% ($p<0.05$). EDV significantly increased by 9.8% ($p<0.05$) by day 5 EMS, but by the end of EMS significant differences disappeared (Tables 1 and 2). In the control group, ESS increased by 17.9 and 22.5% ($p<0.05$) by days 5 and 10 of EMS, respectively, and EDV decreased by 18.4 and 16.6%, respectively ($p<0.001$). In both the control and main groups, no significant changes were observed in other metric, volume, or integral parameters of global LV contractility. Comparison of the global contractility parameters in the main and control groups at the same time points revealed significant predominance of ESV in the main group (by 21%, $p<0.05$). On day 5 of EMS, opposite changes in EDV resulted in predominance of this parameter in main group by 9% in comparison with control ($p<0.05$), while ESV was higher in the main group by 25.2% ($p<0.05$) despite co-directed changes in different groups. No differences were found in metric and integral parameters between groups on day 5 of EMS. By day 10 of EMS, ESS, EDV, and ESV were significantly higher in the main group: by 28.2% ($p<0.05$), 26.7% ($p<0.001$) and 20.1% ($p<0.05$), respectively. The integral parameter of global myocardium contractility, EF, was similar in the control and main groups by the end of EMS course.

Evaluation of baseline parameters characterizing the diastolic function of LV revealed evidences of relaxation disturbances in both control and main groups without any significant intergroup differences. By day 5 of EMS, significant increase in early to late LV filling peak ratio by 19% ($p<0.05$) was found in the main group. Significant differences disappeared on day 10 of EMS. In the control group, only an insignificant trend toward normalization of E/A was noted.

Insignificant trend toward an increase in IVRT was observed in both groups. In the main group, DT increased by 12.6% ($p<0.05$) on EMS day 5, and by 14.6% ($p<0.05$) on EMS day 10 in comparison with baseline values. In the control group, this parameter did not significantly change.

TABLE 1. Dynamics of the Parameters Characterizing LV Functions in the Main and Control Groups (*M*±*SD*)

Parameter	Main group (*N*=37)			Control group (*N*=35)		
	EMS day 1	EMS day 5	EMS day 10	EMS day 1	EMS day 5	EMS day 10
LVPWT, mm	9.8±0.8	10.4±0.7	10.4±0.7	10.1±0.8	10.7±0.7	10.6±0.7
IVST, mm	10.0±0.9	9.9±0.8	10.5±0.9	9.9±0.9	9.7±0.8	9.4±0.7
EDS, mm	52.7±3.1	52.5±3.0	53.3±3.2	50.7±3.3	49.2±2.9	49.3±3.1
ESS, mm	34.6±2.6	35.5±2.5	35.1±2.6	30.7±2.4	32.5±2.6	25.2±2.5
EDV, ml	124.1±5.1	131.3±5.3	136.2±5.7	122.3±4.8	119.5±4.4	99.8±5.0
ESV, ml	50.5±3.0	54.7±3.1	50.9±3.2	39.9±2.8	40.9±2.9	40.7±3.0
EF, %	64.0±3.2	63.2±3.0	64.3±2.8	67.7±3.5	65.8±3.4	68.6±3.2
	*p*1m-1c	*p*5m-5c	*p*10m-10c			
LVPWT, mm	3.0%	2.8%	1.9%			
IVST, mm	1.0%	2.1%	10.5%			
EDS, mm	3.8%	6.3%	7.5%			
ESS, mm	11.3%	8.5%	28.2%*			
EDV, ml	1.5%	9.0%*	26.7%***			
ESV, ml	21.0%*	25.2%*	20.1%*			
EF, %	5.5%	4.0%	6.3%			

Note. m: main group, c: control group. 1, 5, and 10 in inferior index demotes EMS day. *$p<0.05$, ***$p<0.001$.

TABLE 2. Dynamics of Parameters Characterizing LV Functions in the Main and Control Groups

Parameter	Main group (*N*=37)			Control group (*N*=35)		
	p_{1-5}	p_{1-10}	p_{5-10}	p_{1-5}	p_{1-10}	p_{5-10}
LVPWT, mm	5.8%	5.8%	0%	5.6%	4.7%	0.9%
IVST, mm	1.0%	4.8%	5.7%	2.1%	5.1%	3.1%
EDS, mm	0.4%	1.1%	1.5%	3.0%	2.8%	0.2%
ESS, mm	2.5%	1.4%	1.1%	5.5%	17.9%	22.5%*
EDV, ml	5.5%	8.9%*	5.6%	2.3%	18.4%***	16.6%***
ESV, ml	7.7%	0.8%	6.9%	2.5%	2.0%	0.5%
EF, %	1.2%	0.5%	1.7%	2.8%	1.3%	4.1%

Note. p_{1-5}: comparison between baseline (day 1) values and day 5 values, p_{1-10}: and day 10 values, p_{5-10}: comparison between day 5 values and day 10 values. *p<0.05, ***p<0.001.

Intergroup comparison revealed the absence of differences in the ratio of early to late filling peaks. On day 5 of EMS, IVRT and DT increased in the main group by 12.7% (p<0.05) and 9.4% (p<0.05), respectively. On day 10, IVRT was still higher in the main group almost without changes, while DT was higher than in the control group by 13.1% (p<0.05).

Similar non-pathological baseline EDR values were observed in both groups. In the main group, EDR markedly increased (by 28.1%; p<0.001) by day 5 of EMS. Further growth of this parameter was less pronounced and comprised 12.1% (p<0.001) by the end of the course compared to day 5. In the control group, significant increase in this parameter by 21.1% (p<0.001) was observed only by the end of EMS treatment. Comparison of EDR values at different time points revealed its prevalence in the main group by 24% (p<0.001) on day 5, and the same prevalence on day 10 (Table 3).

Evaluation of dynamic interrelation between individual parameters characterizing global LV contractility, its diastolic function, and EDR using Pearson's correlation test revealed a moderate direct correlation between EDR and all investigated parameters in the main group. In the control group, moderate direct and reverse correlations were observed only after comparison of individual volume, metric, and diastolic parameters (Table 4).

Thus, against the background of EMS in subjects with initially modified volume and metric LV parameters, significant changes were found only in individual parameters (EDV increase in the main group and differently directed changes in ESS and a decrease in EDV at different time points in the control group) with the prevalence of predominantly volume parameters in the main group at the end of treatment. EMS did not result in significant intra- and intergroup changes between integral parameter of global LV myocardium contractility, EF.

TABLE 3. Dynamics of EDR in the Main and Control Groups (*M*±*SD*)

Parameter	Main group (*N*=37)			Control group (*N*=35)		
	EMS day 1	EMS day 5	EMS day 10	EMS day 1	EMS day 5	EMS day 10
EDR, %	14.1±0.6	19.6±0.6	22.3±0.7	13.5±0.8	14.9±0.9	17.1±0.9
	p_{1-5}	p_{1-10}	p_{5-10}	p_{1-5}	p_{1-10}	p_{5-10}
	28.1%***	36.8%***	12.1%***	9.4%	21.1%***	12.9%*
	p1m-1c	p5m-5c	p10m-10c			
	4.3%	24.0%$^{+++}$	23.3%$^{+++}$			

Note. m: main group, c: control group. *p<0.05, ***p<0.001 within the group, ^{+++}p<0.001 between groups. 1, 5, and 10 in inferior index demotes EMS day.

TABLE 4. Pearson's Correlation Coefficient (*r*) for Individual Parameters of Electrocardiogram in Subjects from the Main and Control Groups

Parameter	IVST	EDS	ESS	EDV	ESV	EF	E/A	IVRT	DT	EDR
Main group (*N*=37)										
LVPWT	+0.11	+0.07	+0.08	+0.15	+0.06	+0.07	+0.25	+0.13	+0.21	+0.43*
IVST	0	+0.06	+0.07	+0.15	+0.06	+0.05	+0.24	+0.12	+0.20	+0.41*
EDS	0	0	+0.03	+0.10	+0.02	+0.02	+0.20	+0.08	+0.15	+0.38*
ESS	0	0	0	+0.10	+0.10	+0.02	+0.20	+0.09	+0.16	+0.38*
EDV	0	0	0	0	+0.10	+0.09	+0.28	+0.16	+0.23	+0.45*
ESV	0	0	0	0	0	+0.01	+0.20	+0.08	+0.15	+0.40*
EF	0	0	0	0	0	0	+0.20	+0.08	+0.15	+0.37*
E/A	0	0	0	0	0	0	0	+0.26	+0.35*	+0.57*
IVRT	0	0	0	0	0	0	0	0	+0.22	+0.44*
DT	0	0	0	0	0	0	0	0	0	+0.51*
EDR	0	0	0	0	0	0	0	0	0	0
Control group (*N*=35)										
LVPWT	-0.09	-0.08	-0.23	-0.24	+0.07	+0.06	+0.18	+0.09	+0.08	+0.25
IVST	0	+0.08	+0.22	+0.23	-0.07	-0.06	-0.18	-0.09	-0.09	-0.25
EDS	0	0	+0.20	+0.21	-0.05	-0.04	-0.16	-0.06	-0.07	-0.24
ESS	0	0	0	+0.39*	-0.20	-0.02	-0.30*	-0.22	-0.22	-0.39*
EDV	0	0	0	0	-0.20	-0.20	-0.31*	-0.22	-0.22	-0.40*
ESV	0	0	0	0	0	+0.03	+0.15	+0.06	+0.06	+0.23
EF	0	0	0	0	0	0	+0.14	+0.05	+0.05	+0.22
E/A	0	0	0	0	0	0	0	+0.17	+0.17	+0.34*
IVRT	0	0	0	0	0	0	0	0	+0.08	+0.25
DT	0	0	0	0	0	0	0	0	0	+0.25
EDR	0	0	0	0	0	0	0	0	0	0

Note. *Parameters with moderate (0.3 to 0.69) correlation.

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