Effect of Muscle Electrical Stimulation on Electrophysiological Parameters of Cardiac Work in Athletes

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During the period encompassing 10 sessions of the quadriceps femoris muscle electromyostimulation in athletes (n=72), the following cardiac parameters changed significantly: *QT*-interval dispersion and the incidence of supraventricular and ventricular extrasystoles decreased, while the circadian index increased. No significant changes in the temporal- and frequency-domain parameters of the heart rate were observed, although there was a clear trend to normalization of the disturbed sympathovagal balance in the athletes.

Key Words: *electrostimulation; supraventricular and ventricular extrasystoles; QT-interval dispersion; heart rate variability*

Adaptivity of the cardiovascular system in athletes is one of the most important indices reflecting functional status of the whole organism. The following electrophysiological parameters seem to be the most informative adaptivity markers: 1) the level of ectopic (arrhythmic) activity, 2) synchronicity of depolarization and repolarization of various sites in the ventricular myocardium (dispersion of *QT*-interval), 3) temporal- and frequency-domain indices of heart rate variability (HRV), and 4) sympathovagal balance in relation to the sleep and wakefulness phases (all assumed within the nonpathologic electrophysiological range) [2-7]. Electromyostimulation (EMS) affects various metabolic processes in the organism of athlete [8-11]. However, there are no studies addressing to the quantitative assessment of cardiovascular sympathovagal status during EMS.

Our aim was to assess dynamically the electrophysiological status of the heart during EMS.

MATERIALS AND METHODS

The study was carried out on athletes aging 25.3±4.8 years (n=72) specialized in ski racing. The experimental group (n=37) comprised 20 men and 17 women during the restorative training stage (mean age 24.7±4.5 years). The control group consisted of 35 athletes (21 men and 14 women) with patellofemoral arthrosis, which did not exercise during the last 2 months (mean age 25.0±4.3 years). EMS course of the quadriceps femoris muscle was performed for 10 days with a 2-day interval in the middle of this period. This stimulation was performed with Kotz currents (train duration 10 sec, pause 50 sec, modulation frequency 50 Hz, duration of the trapezoids pulse 10 msec, carrier frequency 2500 Hz). Before stimulation and on days 5 and 10 of EMS, the following parameters were assessed: the number of supraventricular and ventricular extrasystoles (SVES and VES, respectively); dispersion of *QT*-interval assessed as the difference between its daily maximum and minimum values (*QTd* in msec); the temporal- and frequency domain HRV parameters (SDNN, msec; PNN50, %; HF, nu; LF, nu; LF/HF), circadian index (CI, a ratio of mean daytime HR to mean nighttime HR). The study did not

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include the persons with frequent SVES, with VES>1 by the Lown grading system, with low time- and frequency-domain HRV parameters, with *QTd*>40 msec, with low indices of global left ventricular contractility, and with dopplerographic indications on the restrictive transmitral flow.

The data were processed statistically at $p<0.05$ using Biostatistics 4.03 software and presented as *m*±*SEM*. Qualitative parameters are given as sample proportions.

RESULTS

Before EMS session, SVES incidence did not differ between the control and experimental groups (15.8%, $p>0.05$) and corresponded to the parameters of infrequent extrasystole. In the experimental group, SVES incidence significantly decreased by 35% and 62% ($p<0.001$) in comparison to the initial level on EMS days 5 and 10, respectively. Similarly, SVES incidence in the control group significantly decreased by 23.0% ($p<0.05$) and 39.3% ($p<0.001$). The comparison of SVES incidence in both groups after termination of EMS session showed that it was significantly lower in the experimental group (by 47.3%, $p<0.001$). The initial values of VES incidence also did not significantly differ between the groups (14.5%, $p>0.05$). In the experimental group, VES incidence insignificantly decreased by 17.5% ($p>0.05$) on EMS day 5, while on day 10 it decreased significantly by 38.8% ($p<0.001$). In the control group, VES incidence significantly decreased on EMS days 5 and 10 by 27.2% ($p<0.05$) and 43.0% ($p<0.001$), respectively, in comparison to the initial level. At all stages of examination, there was no significant intergroup difference in VES incidence. In both groups, the initial time-domain parameters describing the sympathetic and parasympathetic cardiotropic influences significantly surpassed the reference levels. At the same time, the sympathetic and parasympathetic indices of the experimental group were significantly higher than the corresponding values in the control group by 24.1% and 52.9% ($p<0.001$), respectively. EMS produced no significant intra- or intergroup changes in the time-domain HRV parameters assessed at the control stages of the study with an exception of a significant elevation of the parasympathetic component in the experimental group by 16.6% ($p<0.05$). The initial frequency-domain (spectrum) HRV parameters also significantly surpassed the reference levels, although no intergroup or dynamic intragroup differences were observed during EMS course. The prevalence of HF and LF spectrum components in the experimental group by the corresponding values of 35.6% ($p<0.05$) and 31.4% ($p<0.05$) measured at the end of the study resulted from insignificant growth of these parameters observed during the sequential measurements at the stages of examination. No significant intergroup difference in LF/HF ratio reflecting sympathovagal balance was observed after termination of EMS (Tables 1 and 2). Initially equal decrease of CI

TABLE 1. Effect of EMS on Temporal- and Frequency-Domain HRV Indices in Control and Experimental Groups (*M*±*m*)

Index	Experimental group (*N*=37)			Control group (*N*=35)		
	day 1	day 5	day 10	day 1	day 5	day 10
SDNN, msec	259.7±18.6	250.3±19.1	284.1±20.4	197.0±16.1	189.7±17.2	208.3±18.4
RMSSD, msec	93.8±6.8	87.3±6.3	80.0±6.9	49.5±6.0	55.8±5.1	55.1±5.4
pNN50, %	32.7±2.9	35.5±2.7	29.6±2.8	15.4±1.8	18.6±1.9	18.5±1.5
SDNN, msec	24.1%***		24.2%$^{+}$		26.7%^{o}	
RMSSD, msec	47.3%***		36.1%$^{+}$		31.1%^{o}	
pNN50, %	52.9%***		47.6%$^{+++}$		37.5%^{ooo}	
HF, nu	26.6±3.4	26.9±3.0	29.8±2.5	20.4±3.5	19.7±4.2	19.2±4.8
LF, nu	48.8±4.2	53.3±3.5	56.0±3.6	39.8±5.4	38.9±5.3	38.4±5.5
LF/HF	1.8±0.6	2.0±0.5	1.9±0.6	2.0±1.1	2.0±1.2	1.9±1.0
HF, nu	23.3%		26.8%		35.6%^{o}	
LF, nu	18.5%		27.1%$^{+}$		31.4%^{o}	
LF/HF	10.0%		0%		0%	

Note. Dynamics of time- and frequency-domain HRV parameters are given in percentage. ***$p<0.001$, $^{+}p<0.05$ and $^{+++}p<0.001$, $^{o}p<0.05$ and $^{ooo}p<0.001$: comparison of the indices in both groups on EMS days 1, 5 and 10, respectively.

TABLE 2. Dynamics of Temporal- and Frequency-Domain HRV Indices in Control and Experimental Groups

Index	Experimental group (*N*=37)			Control group (*N*=35)		
	$p_{1\text{-}5}$	$p_{1\text{-}10}$	$p_{5\text{-}10}$	$p_{1\text{-}5}$	$p_{1\text{-}10}$	$p_{5\text{-}10}$
SDNN, msec	3.6%	8.6%	11.9%	3.7%	5.4%	8.9%
RMSSD, msec	6.9%	14.7%	8.4%	11.3%	10.2%	1.3%
pNN50, %	7.9%	9.5%	16.6%*	16.8%	16.8%	0.5%
HF, nu	1.2%	10.8%	9.7%	3.5%	5.9%	2.6%
LF, nu	8.5%	12.9%	4.8%	2.3%	3.5%	1.3%
LF/HF	10%	5.3%	5%	0%	5%	5%

Note. $p_{1\text{-}5}$, $p_{1\text{-}10}$, $p_{5\text{-}10}$: comparison of the data obtained on the days shown by the corresponding lower indices 1-5, 1-10, and 5-10.

in both groups resulted from the prevalence of parasympathetic cardiotropic influences at night. In both groups, EMS eliminated the day/night imbalance by elevating the sympathetic influences at night without significant intergroup difference in CI at the end of the study.

Before EMS, *QT* parameter did not differ between both groups (8.3%, $p>0.05$) and ranged within the nonpathological limits. In the experimental group, *QTd* significantly decreased by 52.5% and 61.5% ($p<0.001$) on EMS days 5 and 10, respectively. In the control group, it decreased by 29.3% ($p<0.05$) and 41.7% ($p<0.001$), respectively. It is noteworthy that virtually maximal decrease in *QTd* (by 38.3%, $p<0.001$) was observed in the experimental group as soon as on EMS day 5.

TABLE 3. Pearson Correlation (*r*) of ECG Parameters in Control and Experimental Groups

Index	VSE	QTd	SDNN	PNN50	HF	LF	LF/HF	CI
Experimental group (*N*=37)								
SVES	+0.97*	+0.98*	-0.71*	+0.71*	-0.73*	-0.75*	-0.68^{+}	-0.72*
VES	0	+0.91*	-0.47^{+}	+0.48^{+}	-0.49^{+}	-0.51^{+}	-0.44^{+}	-0.49^{+}
QTd	0	0	-0.69^{+}	+0.71*	-0.73*	-0.75*	-0.68^{+}	-0.72*
SDNN	0	0	0	-0.18	+0.19	+0.21	+0.14	+0.19
PNN50	0	0	0	0	-0.16	-0.23	-0.15	-0.20
HF	0	0	0	0	0	+0.24	+0.16	+0.21
LF	0	0	0	0	0	0	+0.18	+0.23
LF/HF	0	0	0	0	0	0	0	+0.16
Control group (*N*=35)								
SVES	+0.82*	+0.80*	-0.44^{+}	-0.55^{+}	+0.45^{+}	+0.44^{+}	+0.44^{+}	-0.45^{+}
VES	0	+0.84*	-0.48^{+}	-0.62^{+}	+0.49^{+}	+0.47^{+}	+0.48^{+}	-0.48^{+}
QTd	0	0	-0.47^{+}	-0.59^{+}	+0.48^{+}	+0.44^{+}	+0.47^{+}	-0.48^{+}
SDNN	0	0	0	+0.22	-0.10	-0.09	-0.10	+0.10
PNN50	0	0	0	0	-0.23	-0.08	-0.23	+0.22
HF	0	0	0	0	0	+0.09	+0.11	-0.12
LF	0	0	0	0	0	0	+0.09	-0.09
LF/HF	0	0	0	0	0	0	0	-0.11

Note. The parameters with $^{+}$middle (0.30-0.69) and *strong (0.70-1.0) correlation are symbolized.

Assessment of the dynamic interrelations between some examined parameters characterizing various aspects of the autonomic imbalance using Pearson correlation test revealed strong or moderate correlation (positive or negative) only between the following indices (with stronger correlation in the experimental group): SVES, VES, *QTd*, CI, time- and frequency-domain HVR parameters. Correlation between time- and frequency-domain HVR parameters was weak in both groups, which probably results from their correspondence to various aspects of sympathovagal imbalance (Table 3).

Thus, significant decrease in SVES and VES incidence was observed during EMS course (within the range of initial nonpathological values) with larger significant drop in SVES documented in the experimental group to the end of EMS course. Comparison of initial time-domain HRV parameters revealed their significant prevalence in the experimental group. During EMS course, the difference in the time-domain HRV parameters between the control and experimental groups became less significant due to more pronounced dynamics of parasympathetic influences. While there were no initial intergroup differences in the frequency-domain HRV parameters, the experimental group demonstrated even and significant elevation of HF and LF indices during EMS. Initial decrease of CI in both groups was accompanied by prevalence of the parasympathetic influences at night, while EMS eliminated this day/night sympathovagal imbalance due to up-regulation of sympathetic influence during the night, primarily in the experimental group. Assessment of dynamic interrelation between some examined parameters revealed strong and moderate correlation between the heart rhythm disturbances, *QT*-interval dispersion, HRV temporal and spectrum indices in both groups with some prevalence in the experimental cohort. However, no definite dynamic interdependence between the time- and frequency-domain HRV parameters was observed.

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REFERENCES

1. V. V. Ar'kov, T. F. Abramova, T. M. Nikitina, *et al*., *Byull. Eksp. Biol. Med.,* **149**, No. 2, 135-138 (2010).
2. R. M. Baevskii, *Klin. Inform. Telemed.*, No. 1, 54-64 (2004).
3. N. Yu. Zakharova and V. P. Mikhailov, *Vestn. Aritmol*., No. 36, 23-26 (2004).
4. L. M. Makarov, *Kardiologiya*, No. 1, 98-102 (2002).
5. A. N. Parkhomenko, A. V. Shumakov, and O. I. Irkin, *Ibid.*, No. 4, 83-86 (2001).
6. A. N. Ragozin, *Vestn. Aritmol*., No. 21, 37-40 (2001).
7. A. V. Frolov, *Klin. Inform. Telemed.*, No. 1, 32-36 (2005).
8. A. Grunovas, V. Silinkas, J. Poderys, and E. Trinkunas, *J. Sports Med. Phys. Fitness*, **47**, No. 3, 335-343 (2007).
9. D. M. Hettinga and B. J. Andrews, *Neuromodulation*, **10**, No. 3, 291-297 (2007).
10. J. Leijnse, S. Carter, A. Gupta, and S. McCabe, *J. Neurophysiol*., **100**, No. 1, 64-75 (2008).
11. B. Saltin and J. W. Helge, *Ugeskr Laeger,* **162**, No. 15, 2159-2164 (2000).