EXAMINATION OF HEART RATE DURING RECOVERY PERIOD OF STRESS TEST

A.L. Pokhachevsky, associate professor, Ph.D.
Research Laboratory "Diagnostic and health technologies", Volgograd
N.V. Ankudinov, Dr. Hab.
Academy of the Federal Penitentiary Service of Russia, Ryazan
V.Yu. Shabanov, postgraduate student
Velikie Luki State Academy of Physical Culture, Velikie Luki

Key words: heart rate, diagnostics, autonomic control, health, and youth.

Introduction.

Doctors of medical exercises dispensaries, sport schools and teams face the necessity to provide objective estimation not only for a health condition of a person involved in daily physical exercise, but for his/her competition form, to determine his/her training status. To achieve that, heart rate analysis, using the methods developed by us, is one of several possible variants for objectification of the functional state of the organism.

Heart rate (HR) is a responsive indicator of the CNS regulatory impacts. Reflection of the environmental impacts in afferent signals refracting at cortical, subcortical and spinal levels as efferent impulsing and humoral and metabolic activity responds in fine HR variability, thus providing the latter with a high prognostic information capacity.

The analysis of the neurohumoral regulation as an independent factor influencing the physical state of a person and to a large extent limiting the working capacity [1] and a question of investigation for methods of its analysis have determined the fundamental objective of the present study.

Materials and methods.

Stress test.

The maximal cycle ergometer test was performed of an individual record [3, 7]. The capacity W of the first stage lasting for three minutes is calculated based on the value of a due basal metabolic rate (DBM) in kilocalories according to the formula W=DBM × 0,1 (DBM is determined by a Harris-Benedict table) [1]. Further the load was incrementally increased every minute by 30 W by an individual value indicating the load end and the beginning of a recovery period lasting for 7 minutes.

During the entire testing, cardial analyzer «PolySpectr-12» (Neurosoft) recorded a digitized electrocardiogram, from which an array of R-R intervals was distinguished – a cardiac rhythmogram (CRG), mathematically processed using ingenious methods.

CRG variability in the recovery period was evaluated using the linear model: Y=aX+b, where X – recovery time in seconds, Y – duration of an R-R interval in seconds, a (MC1) and b (MC2) – model parameters – dynamic markers of recovery, characterizing the recovery rate and its constant (average) component respectively.

To the time series resulted from a CRG by subtracting trends, the fast Fourier transformation is applied at a section of 64 intervals long with a step of one. Spectrum variability within ranges (Hz): 0.15 – 0.4 (HF) and 0.04 – 0.15 (LF) was modeled using the linear regression. We considered: variability rate of sympathetic (LFl), parasympathetic (HFl) activity [4, 5].

The results were processed using the statistics package Statistica 6.0. In respect that the value distribution differed from the standard, the data are represented in the form of a 50-th (median), 25-th and 75-th percentile (Pc), and to process them, nonparametric techniques methods are used such as: Spearman, Mann-Whitney.

To study the dependence between HR abnormalities and vegetative activity and mixed endurance development, and also to resolve the issues of their prevention, we have analyzed 272 CRGs of a maximal load test obtained during the examination of a mixed population (S) of pupils at the age of 17±2. The latter included both not physically trained young people (mainly sedentary behavior) and competitive athletes in cyclic sports. In this regard, the fundamental insufficiency of subjective subdivision of the sampling by the anamnestic attribute was resolved by the cluster analysis (k-means clustering) of individual distributions of RR intervals in the load testing. Thanks to the objective selection of three clusters (1, 2, 3) of groups including 74, 97 and 61 testees respectively the entire collection of individual load tolerance was considered.

Results and discussion.

HR abnormalities were revealed during the stress test in the form of transient changes of conduction at early stages of the recovery period. The phenomenon exerted by CRG as the presence of 1 – 3 groups of 5 - 7 alternating long and short RR intervals with the following return to the initial duration level; on an ECG – the transient proximal (nodal) first-degree atrioventricular block.

The analysis of the reasons for revealed abnormalities (both in the binary form and quantitively – by the number of abnormality groups) proved the absence of any relation with external factors: endured load power, average and maximal heart rate. The revealed rhythm disturbance being not life-threatening by nature, can be markers of vegetative disorder of the HR regulation, as the latter is a very responsive indicator of the preclinical body state [1, 2, 6].

Evaluation of main parameters of physical fitness in a mixed population revealed the age uniformity of cluster groups disrupted by the substantial predominance of the Quetelet index in group 3 (groups 1, 2 p<0.005), including both mass value (groups 1, 2 p<0.01) and growth (group 1 p<0.01). In this case differences between test parameters of group 1 and 2 are minimal.

The discovered features of physical development are refracted by the importance of differences in load tolerance and its regulation. At that, the increase in the vegetative activity in the recovery period mediated by load tolerance extension is an objective marker of the endurance development and improvement of adaptation capabilities of an organism. In this regard, the increase in load tolerance and intensification of its vegetative provision in a cluster row (3 – 1) enables to determine the endurance development as the main trait of cluster differences (Table 1).

Following the present study, vegetative impacts of a recovery period that determine HR fall during the endurance development are ensured by an increase both in sympathetic and parasympathetic responsibility, at this the latter is critical. In this case the present HR abnormalities onset within groups is decreased as far as the recovery rate is increased and the vegetative control is strengthened. In its turn, the presence of transient blocks in clusters 1 – 3 is definitely related with the recovery rate ($r_{1\text{-}3}$ = 0.74, 0.7, 0.62; $p<0.05$), low-frequency – LF ($r_{1\text{-}3}$ = -0.48, -0.29, -0.37; $p<0.05$) and high-frequency – HF ($r_{1\text{-}3}$ = -0.38, -0.15, -0.25; $p<0.05$) dynamics.

The respective increase of the number of blocks in relation to the heart rate recovery rate decrease shows the involvement of HR regulation in the recovery period improvement. HR abnormalities at the low level of sympathetic and parasympathetic control confirm this conclusion. The cluster level in fact does not change the revealed regularity. A negligible decrease of correlation relationships (cluster 2, 3) is determined by an increasingly larger role of a load component that requires additional recovery resources. Herein the relationship of HR abnormalities with the endured load is considerably increased only in cluster 3 (0.14, 0.01, 0.64 respectively).

The level and dynamics of the regulation threshold of HR abnormalities by the meaning of CRG model criteria (Table 2) that determine the recovery rate correspond with their minimal quartile level (in a cluster) and speak for the increase of HR stability against noncardiac impacts in conditions of the endurance development. At that, the likelihood of the arrhythmia onset is cut at the increase of the rate and the respective decrease of heart rate in the recovery period.

Conclusions.

1. Vegetative activity in the recovery period is considerably increased depending on the endurance development level, at that parasympathetic impacts prevail over sympathetic ones. Vegetative depression, determined by a considerable activity decay of both branches, provides a decrease in the recovery rate and can manifest itself as transient HR abnormality.

2. HR vegetative control during physical exercises together with its abnormality phenomena require further study. The present need is imposed not so much by prevention of life-threatening cases of arrhythmia, as by the early detection of the exercise learning by an organism and preventive measures against overload and overtraining effect.

Table 1. *Load tolerance and recovery markers.*

Group*	Percentile	W	MC1	MC2	LFh	HFh
S	25	150,0	84,53	69,21	2,16	3,49
	50	210,0	94,64	81,37	6,83	11,69
	75	240,0	101,29	93,14	20,28	36,24
1	25	90,0	82,29	86,87	0,86	0,84
	50	120,0	86,19	99,13	1,59	2,22
	75	150,0	94,86	111,50	4,10	6,06
2	25	180,0	82,97	78,87	2,88	3,92
	50	195,0	93,35	84,87	6,09	9,09
	75	230,0	100,85	90,93	9,40	16,37
3	25	235,0	92,22	58,01	14,45	13,92
	50	240,0	98,60	63,86	29,13	52,74
	75	270,0	105,58	69,79	46,75	113,51

* – differences by multiple Kruskal-Wallis and paired Mann-Whitney comparisons are essential ($p<0.05$)

Table 2. *CRG criteria against typical recovery period arrhythmia*

Model criterion	Clusters					
	1		2		3	
	AV	CI	AV	CI	AV	CI
MC1	82,11	74.2 – 90.0	85,87	82.4 – 89.3	94,10	90.8 – 97.4
MC2	114,32	111.4 – 117.2	105,1	101.1 – 109.1	81,34	78.5 – 84.2

AV – average value; CI – confidence interval

References

1. *Mikhaylov, V.M.* Stress Testing with ECG monitoring: cycle ergometry, treadmill test, step test, walking / V.M. Mikhaylov. - Ivanovo: Talka, 2008. – 545 P. (In Russian)
2. *Ordzhonikidze, Z.G.* Features of athlete’s ECG / Z.G. Ordzhonikidze, V.I. Pavlov, A.E. Druzhinin // Funktsional’naya diagnostika. – 2005. – № 4. – P. 65–74. (In Russian)
3. *Pavlov, V.I.* Comparative analysis of load testing using different types of ergometers / V.I. Pavlov, A.V. Pachina, Z.G. Ordzhonikidze // Sportivnaya meditsina: nauka i praktika. – 2011. – V. 1, № 2. – P. 5–10. (In Russian)
4. *Pokhachevsky, A.L.* A method for determining exercise tolerance on the point of escaping heart rate in the autonomic control / A.L. Pokhachevsky, B.A. Sadel’nikov, V.M. Mikhaylov // Invention patent № 2355301, priority 23.11.2007. (In Russian)

5. *Pokhachevsky, A.L.* A method for determining the autonomic activity during stress test / A.L. Pokhachevsky, B.A. Sadel’nikov // Invention patent № 2468740, priority 21.03.2011. (In Russian)
6. *Shkol'nikova, M.A.* Life-threatening arrhythmias in children / M.A. Shkol'nikova. – Moscow: Neftyanik, 1999. – 229 P. (In Russian)
7. *Minkkinen, M.* Enhanced Predictive Power of Quantitative TWA During Routine Exercise Testing in the Finnish Cardiovascular Study / M. Minkkinen, M. Kahonen, J. Viik et all. // Journal of Cardiovascular Electrophysiology. – 2009. – Vol. 20, N 4. – P. 408–415.