TELEMETRY AND INFORMATION TECHNOLOGIES IN DIAGNOSIS OF SPORTSMEN FUNCTIONAL STATE

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The aim of the investigation was to develop the instrumental methods for a full assessment of sportsmen functional state in the process of training and competition activity.

Materials and Methods. 57 sportsmen (professional athletes and amateur sportsmen) aged 14–24 years participated in the survey; 20 from them were female, and 37 male. In the study the following techniques were used: computer laterometry, computer campimetry, wireless (telemetry) cardiointervalography. The results were processed using standard methods of parametric and nonparametric statistics.

Results. There has been stated that computer laterometry enables to reveal cognitive strain in training time that can be a marker of "ineffective" state. Computer campimetry findings give the evidence of emotional state change on exertion. However, the most informative indicator of a sportsman functional state is the total power of heart rate variability spectrum. The comparison of the results obtained using the full assessment with clinical data of professional sportsmen of the experimental group showed continuous monitoring of heart rate in the process of training to be an effective screening technique of cardiovascular diseases. The application of wireless cardiointervalography enabled to monitor the sportsmen state effectively and noninvasively at all the stages of training and competition process.

Key words: functional state monitoring; information technology; telemetry; sports medicine.

Currently, achievement of good results in sports is related to damaging exercises and is the source of risk of disease development and professional traumas in sportsmen. In this regard, there assume great importance the assessment and prognosis of sportsmen functional state in the context of training and competition activities, and it determines the development of noninvasive instrumental methods to perform the assessment and prognosis.

The aim of the investigation was to develop the instrumental methods for a full assessment of sportsmen functional state in the process of training and competition activity.

Materials and Methods. In our study we used new information and telecommunication technologies providing on-line detection of psychophysiological markers of optimal and extreme conditions and enabling to make prognostic decisions of individual schedules of sportsmen professional load.

*1. Computer laterometry***.** The measurements are based on dichotic stimulation method [1, 2]. To process the results we suggest the following advanced values:

$AS_{min}=(\Delta t_{min}\ right-\Delta t_{min}\ left)/(\Delta t_{min}\ right+\Delta t_{min}\ left)$;

$AS_{max}=(\Delta t_{max}\ right-\Delta t_{max}\ left)/(\Delta t_{max}\ right+\Delta t_{max}\ left)$;

$AS_{cleav}=(\Delta t_{cleav}\ left-\Delta t_{cleav}\ right)/(\Delta t_{cleav}\ left+\Delta t_{cleav}\ right)$;

$AS=\sqrt{(AS_{min}^2+AS_{max}^2+AS_{cleav}^2)}$, where AS — hemispheric asymmetry coefficient, AS_{min}, AS_{max}, AS_{cleav} — asymmetry coefficient on Δt_{min}, Δt_{max} values and Δt cleavage.

The measurements were taken before and after training load in a quiet room.

*2. Computer campimetry***.** According to this technique [1, 2] we measured differential thresholds on shade scale (chromatic thresholds) within the framework of HLS model. For processing of the results we used the following parameters:

R_{max} — maximum differential threshold in red shades (H belongs to 20–230 CU range);

G_{max} — maximum differential threshold in green shades (H belongs to 60–90 CU range);

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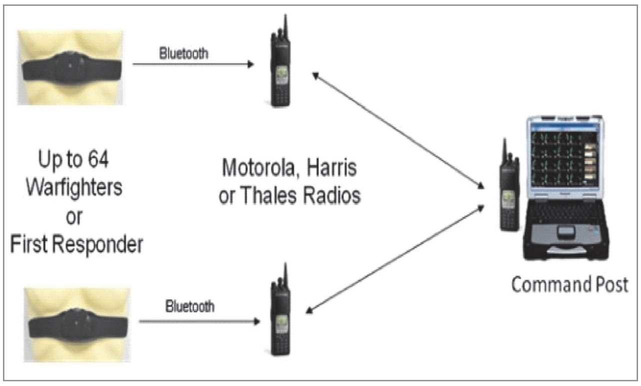


Fig. 1. Principal diagram of program apparatus complex of wireless cardiointervalography

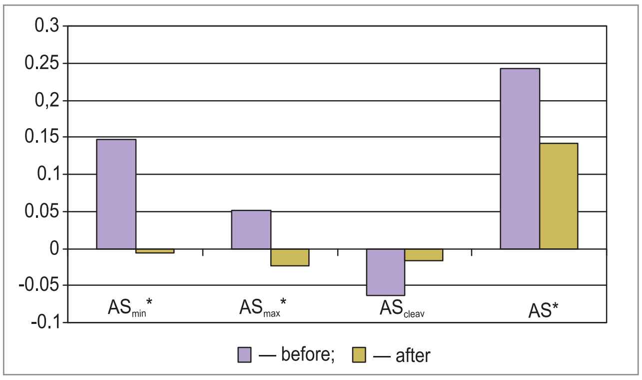


Fig. 2. Mean values of hemispheric asymmetry coefficients before and after load; * — p≤0.05

B_{max} — maximum differential threshold in blue shades (H belongs to 160–190 CU range).

The measurements were performed before and after training load.

3. Wireless cardiography. The analysis of cardiac rhythm regulation enables to retrieve information on functional status and features of adaptive behaviour of the whole body, and is actively used in sports medicine. The signals were recorded using telemetric system BioHarness (USA) — cardiosignal-recording device built in a belt. A signal is transmitted from a sensor to smartphone, and from smartphone — to a computer through Bluetooth (Fig. 1).

The measurements were taken in the process of training load in gym, as well as before and after training at rest — a test subject was resting in an armchair for 5 min. For data processing we used spectral methods of heart rate variability analysis: 1) periodogram technique used for analyzing the following parameters: total power of heart rate variability spectrum — TP (ms^2), power of rhythmogram spectrum in very low frequencies — VLF (ms^2), power of rhythmogram spectrum in high frequencies — HF (ms^2), power of rhythmogram spectrum in low frequencies — LF (ms^2), the correlation of rhythmogram spectra in low and high frequencies (autonomic balance coefficient) — LF/HF, and 2) continuous wavelet-transformation method (wavelet-spectrograms were analyzed).

The results were processed using parametric (Student t-test) and nonparametric (Wilcoxon-Mann-Whitley tests) methods.

57 sportsmen participated in the survey, among them 29 professional rowers aged 14–18 years (14 young women and 15 young men) with qualifications from I category to master of sports, from School of Olympic reserve, and 28 amateur sportsmen (team sports: basketball, volleyball) aged 14–24 years (6 young women and 22 young men).

Results and Discussion. The study of physical load effect on functional hemispheric asymmetry level showed statistically significant decrease of asymmetry level after load on the following parameters: AS_{min}, AS_{max} and AS (Fig. 2).

This effect indicates cognitive strain in the course of training load and can be a marker of "non-effective" condition [3–5].

According to the analysis results of chromatic thresholds in their initial state, the test subjects were divided into three groups (Fig. 3):

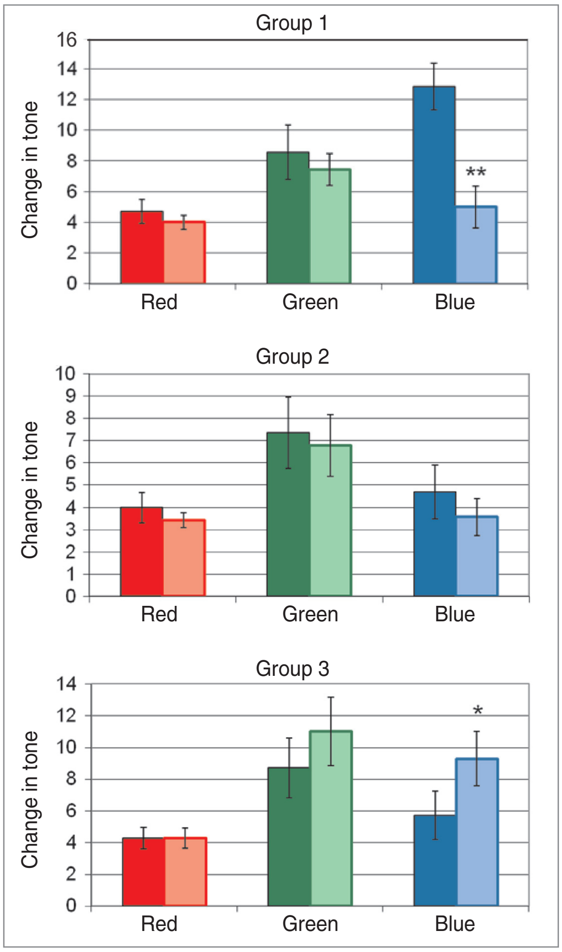


Fig. 3. Dynamics of chromatic thresholds in groups before (dark columns) and after (light columns) training; * — statistically significant difference with initial level, p<0.05, ** — p<0.01 (according to Student t-test)

Group 1 — maximum chromatic threshold in red shades — 15 %;

Group 2 — maximum chromatic threshold in green shades — 60 %;

Group 3 — maximum chromatic threshold in blue shades — 25 %.

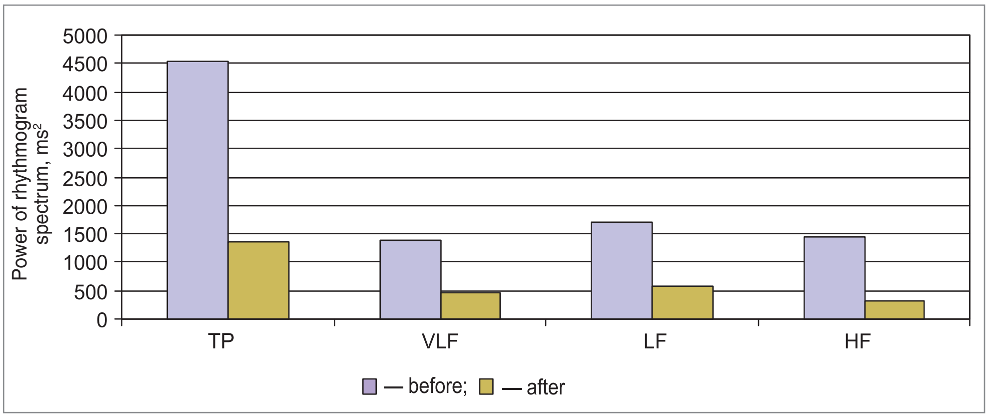


Fig. 4. Mean values of spectral analysis of heart rate variability before and after load

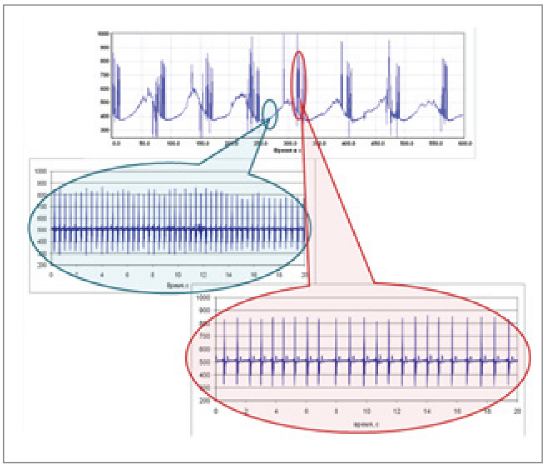


Fig. 5. Comparison of rhythmogram (upper diagram) and electrocardiogram (two lower diagrams) simultaneously recorded by wireless cardiointervalography

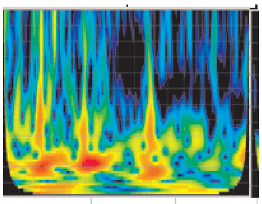
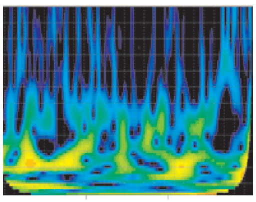
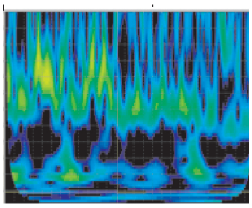
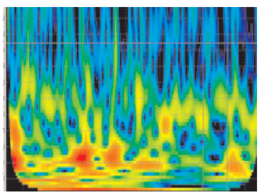
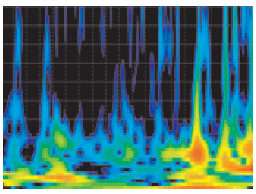
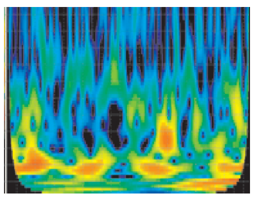
	Stretching before training load	Intensive training load	Rest after intensive training
A			
B			

Fig. 6. Dynamics of autonomic regulation values at different training stages. *A*, *B* — wavelet-analysis of rhythmograms of sportsmen of group 1 and group 2

As the result, we revealed significant changes of values in the group with maximum differential threshold in blue. After training load, blue shades perception thresholds appeared to decrease significantly (p=0.0022) that indicates the improvement of emotional state in the group with initial strain [3, 6].

The monitoring of sportsmen functional state in the course of training load enabled to obtain data on heart rate dynamics and the autonomic regulation modes in accordance with the dynamics of training load (Fig. 4).

Heart rate variability values of spectral analysis were found to decrease statistically significantly ($p<0.05$) after training load that gives the evidence of exhaustion of autonomic regulation systems [6].

Moreover, the analysis of individual cardiointervalograms in the great majority of research subjects (96%) revealed

Optimal parameters of sportsmen autonomic regulation

Index	M	m
Cardiac rate, bpm	78.40	4.53
Total power, ms^2	3653.82	211.81
VLF, ms^2	1182.70	100.80
LF, ms^2	1604.49	87.59
HF, ms^2	573.29	61.01
LF/HF	3.09	0.86

substantial heart rate disturbance (Fig. 5) that coincided statistically significantly ($p<0.05$) with the results of their physical examination.

We distinguished two groups of sportsmen when classifying the sampling on the dynamics of regulatory systems activity indices (Fig. 6):

1) sportsmen with exhaustion of autonomic regulation resources due to training load;

2) sportsmen resistant to training loads.

The differences between sportsmen of different groups are manifested even in warm-up. The obtained data enabled to determine optimal ranges of initial (in the course of warm-up) parameters of heart rate variability, in which individual risk of regulatory resources exhaustion in the course of training is minimized (See Table).

The correlation analysis revealed high correlation degree between hemispheric asymmetry coefficient (AS) and competitive effectiveness ($r=0.875$; $p<0.05$), as well as between the values of differential thresholds in blue and green shades and the efficiency of team sport activity ($r=0.843$; $p<0.05$).

Conclusion. Computer laterometry technique enables to reveal significant cognitive strain in the course of training load that can be a marker “non-effective” state. Computer campimetry data give the evidence of the emotional state change in the course of loading. However, the most informative indicator of sportsman functional state is total power of heart rate variability spectrum. Such parameters, as instantaneous heart rate and sympathetic activation index prevent from prompt detection of autonomic regulation failure. The comparison of the findings obtained by means of a full assessment and physical examination data showed continuous heart rate monitoring in the course of training to be effective screening technique of cardiovascular disorders. The use of wireless cardiointervalography enables to monitor sportsmen state effectively and noninvasively at all stages of training and competition process.

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References

1. Antonets V.A., Polevaya S.A., Kazakov V.V Handtracking: issledovanie pervichnykh kognitivnykh funktsiy cheloveka po ikh motornym proyavleniyam. V kn.: *Sovremennaya eksperimental’naya psikhologiya* [Handtracking: the study of human primary cognitive functions by their motor manifestations. In: Modern experimental psychology]. Pod red. Barabanshchikova V.A. [Barabanshchikov V.A. (editor)]. Moscow: Izd-vo IP RAN. 2011; Vol. 2, p. 39–54.

2. Yakhno V.G., Polevaya S.A., Parin S.B. Bazovaya arkhitektura sistemy, opisyvayushchey neyrobiologicheskie mekhanizmy osoznaniya sensornykh signalov. V kn.: *Kognitivnye issledovaniya* [Basic architecture of the system describing neurobiological mechanisms of sensor signal perception. In: Cognitive investigations]. Pod red. Aleksandrova Yu.I., Solov’eva V.D. [Aleksandrov Yu.I., Solov’ev V.D. (editors)]. Moscow: Izd-vo IP RAN; 2010; Issue 4, p. 273–301.

3. Parin S.B., Polevaya S.A., Efimova N.V. *Vestnik NNGU im. N.I. Lobachevskogo. Sotsial’nye nauki — Herald of N.I. Lobachavsky Nizhny Novgorod State University. Social sciences* 2006; 1(5): 66–78.

4. Polevaya S.A. *Vestnik NGU — Nizhny Novgorod State University Reporter* 2008; 2: 106–117.

5. Polevaya S.A., Antonets V.A., Eremin E.V. *Sensornye sistemy — Sensor systems* 2002; 16(4): 291–296.

6. Runova E.V. *Veyvlet-analiz variabel’nosti serdechnogo ritma v otsenke funktsional’nogo sostoyaniya regulyatornykh sistem organizma cheloveka.* Avtoref dis. … kand. biol. nauk [Wavelet-analysis of heart rate variability in the assessment of functional state of human regulatory systems. Abstract for Dissertation for the degree of Candidate of Biological Science]. Nizhny Novgorod; 2008.