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Danylo Halytsky Lviv National Medical University, Department of Physiology

LYUBOV PANINA, YURIY PETRYSHYN, SVITLANA KOVALCHUK, OLEKSIY MYSAKOVETS

Heart rate variability under interval hypoxic training and hemic hypoxia

Zmienność częstości akcji serca w warunkach przerywanego treningu hipoksemicznego i hipoksji hemowej

Development and investigation of the efficiency of preventive and corrective actions directed at the increase of the functional potential of an organism in the face of environment toxic factors are nowadays one of the main tasks of medicine. The lines of effective ways of adaptation to interval stressful influences due to the training of protective mechanisms of an organism at level local stress limiting links and central regulative systems are considered [1, 4, 10].

The purpose of our work was experimental research of the organism functional activity in the conditions of interval hypoxic trainings and hemic hypoxia, induced by nitric intoxications, with the application of heart rate variability (HRV) analysis.

MATERIAL AND METHODS

The experiment was performed on nonlinear male rats with the weight of 180–220 g, and the heart rate (360.0 ± 4.3) beat/min. Animals were divided by resistance to hypoxia using the method of Berezovskyi V.A [5]. The criterion of rats' resistance to oxygen deficiency at the exposition in a flow and ebb pressure chamber at conditional "height" of 11000 m was the time from the moment of "lift" (speed of 180 m/s) to the occurrence of the second agonal breath. Rats corresponding to high resistant (up to 20 min) by the time of "staying" on height were not discovered in the research population. That is why all animals were divided into 2 groups (20 in each): up to 2 minutes – it is conditional low resistant, and up to 12 minutes – conditionally high resistant. 10 days after the test of resistance to hypoxia the interval hypoxic training (IHT) was carried out during 10 days in a flow and ebb pressure chamber at lift on "height" of 3000 m (1st day – 1000 m, 2nd – 2000 m, 3rd and the following – 3000 m) in the following mode: 5 séances for 10 minutes with a break for 15 minutes [4, 10] The speed of " lift on height " – 20 m/s. Sodium nitrite ($NaNO_2$) solution (20 mg/kg) was injected intraperitonealy. HRV analysis was carried out during the peak of methemoglobin formation (near 40% of basic consist of hemoglobin), which is observed 1 hour after injection of nitro compound [7–9]. The record of peripheral pulse was carried out on non anesthetized animals with the use of photopletismographic transmitter attached near the base of the tail. HRV analysis was carried out in the following frequency ranges: Low Frequency (0.015– 0.25) Hz, Mid Frequency (0.25–0.75) Hz, High Frequency (0.75–3.0) Hz [6].

RESULTS AND DISCUSSION

In our research, under injection of sodium nitrite after preliminary usage IHT course in all animals the increase of heart rate by (15–30) beats/min, comparing with IHT was observed. Injection of nitro compound to control animal caused increased heart rate in all animals by (100–125) beats/min, comparing with control. The heart rate of all control animals after hypoxic trainings was decreased by (5–20) beats/min, compared with the initial level. Nowadays, stress, in particular caused by hypoxia, is considered as a nonspecific component of adaptation due to which energetic and plastic reserves of an organism for specific adaptive reorganization of various systems are mobilized [7–9]. At the same time, hypoxic influences can be as a way of training an organism's protective mechanisms. Thus in organisms adapted to stress under conditions of extreme influences, preservation of the functional activity level of cardiovascular system corresponding to an organism's needs is more durable than in control [10]. It is realized due to the increase in capacity of the adrenergic regulation of heart and systems which provide its economical functioning. It thus explains the differences of heart rate revealed by us in animals adapted and unadapted to hypoxia.

A decrease of SDNN, RMSSD, CV in all animals under conditions of hemic hypoxia on IHT background, comparing with IHT application (Fig. 1) was revealed. Thus, the value of standard deviation of NN-intervals (SDNN) decreased on average by 60% both in high (6.72 ± 0.73 vs 16.75 ± 1.58 ms, $P < 0.05$), and in low resistant animals (3.74 ± 0.43 vs 9.31 ± 0.91 ms, $P < 0.05$), comparing with IHT application. SDNN changes marked in high resistant animals did not differ compared with control, and in low resistant were lower by 43%. RMSSD was decreased 2.7 times (8.59 ± 0.91 vs 23.17 ± 2.26 ms, $P < 0.05$) under injection of nitrite after the course of IHT in high resistant animals, comparing with IHT, thus not differing statistically from control. In low resistant rats RMSSD decreased by 72% (2.75 ± 0.31 vs 9.83 ± 0.99 ms, $P < 0.05$), comparing with IHT, and by 52% (2.75 ± 0.31 vs 5.75 ± 0.65 ms, $P < 0.05$), comparing with control. The coefficient of variation (CV) under the studied conditions in high resistant rats was decreased 2.4 times, comparing with IHT, in reference to control. In low resistant animals a decrease of CV by 55%, comparing with IHT, and by 39%, in reference to control was observed.

It is known that SDNN, RMSSD, CV parameters characterize the activity of regulation autonomic contour [2, 3]. Index of centralization (IC) calculated according to spectrographic analysis: IC = (HF+MF)/LF was characterized by central regulating influences on cardiovascular system [2]. In our research in high resistant animals under sodium nitrite injection after hypoxic trainings a decrease of IC by 24%, comparing with IHT, with approximation to initial level was registered. In low resistant animals after nitro compound injection on IHT background, IC parameter was decreased by 54%, comparing with IHT application, and by 61%, comparing with the initial level. As it was known, the total power of spectrum (TP, Total Power) corresponds to the total absolute level of activity regulative systems. In our study in high resistant animals under nitro compound injection after a previous hypoxic trainings decrease TP by 10.5 times (29.16 ± 2.95 vs 305.97 ± 26.07 ms^2, $P < 0.05$), comparing with IHT was marked, which statistically did not differ from control (Fig. 1). In low resistant rats, the injection of sodium nitrite after IHT course led to a decrease of total spectrum power 7 times (6.47 ± 0.70 vs 45.26 ± 4.82 ms^2, $P < 0.05$), comparing with IHT, and 3.4 times (6.47 ± 0.70 vs 21.94 ± 2.03 ms^2, $P < 0.05$), comparing with control (Fig. 1).

It is necessary to note that under injection of sodium nitrite to control rats an increase of SDNN by 5.4 times in high resistant and 3.8 times in low resistant animals, comparing with control, according to the norm of high resistant (5.72 ± 0.26) ms and low resistant rats (6.79 ± 0.63) ms was observed. It was similar to changes of standard deviation of NN-intervals (SDNN), and also RMSSD and CV in both groups of animals, elevation of total power of spectrum was observed. TP was increased in high- and low resistant experimental rats 28 and 27 times, in reference to the norm of high resistant (33.76 ± 2.95) ms^2 and low resistant animals (21.94 ± 2.03) ms^2. Index of centralization was decreased by 20% (2.81 ± 0.26 vs 3.55 ± 0.32, $P < 0.05$) in high resistant animals under hemic hypoxia, comparing with control, whereas in low resistant this parameter was increased 3 times (3.65 ± 0.41 vs 1.21 ± 0.16, $P < 0.05$), comparing with the initial control level.

The unidirectional changes of SDNN, RMSSD, CV, and also the total power of spectrum in high- and low resistant rats under conditions of sodium nitrite injection to control animal testify to an excessive elevation of the activity of the regulative systems, in comparison with such changes under conditions of hemic hypoxia on the basis of IHT application (Fig. 1). As it was known, excessive mobilization of the organism's reserves, caused by the action of environment toxic factors on organism can lead to their exhaustion in the future [7–10]. Thus, stress-reaction of such type can initiate the development of various functional disturbances.

HRV changes established under hemic hypoxia after IHT course application can probably have some explanations. In particular it was known that in trained organisms at the application of optimum selected modes interval hypoxia, as a result of changed morphometric and hemodynamic parameters of heart activity, the influence on pacemaker activity of sinoatrial node of several stressors considerably decreased. Judging from the elevation of statistical and spectral-wave parameters HRV marked by us in IHT application, the activity regulatory systems of an organism had adaptive mobilization character (Fig. 1). Obviously, it allowed preventing the functional overactivation of an organism of animals under conditions of hemic hypoxia.

Scatterogrammes also confirmed the positive effect of interval hypoxia training. The analysis of correlation rhythmogrammes (scatterogrammes) is considered informative for the diagnostics of arrhythmia [2, 3]. The presence of typically dense points placed on both sides of the base on scatterogrammes in animals of both groups in hemic hypoxia was registered (Fig. 2). Such changes are usually registered in extrasystolia [3]. Scatterogrammes of animals that were exposed to IHT and the injection of sodium nitrite were characterized by the presence of small extraordinary contraction (Fig. 3).

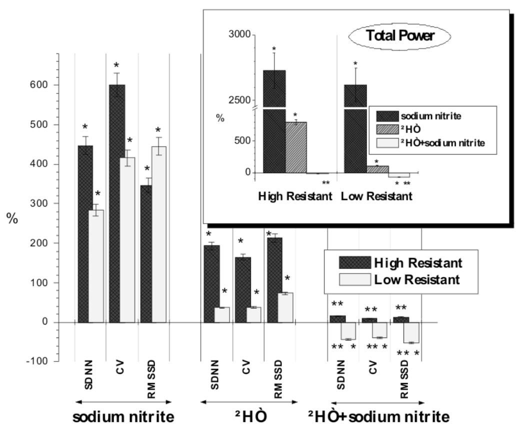

Fig. 1. Changes of HRV statistical characteristics under hemic hypoxia and interval hypoxic training (IHT), in comparison with control (0%). Values are means ± SE. * $P < 0.05$, compared with control; ** $P < 0.05$, compared with IHT group

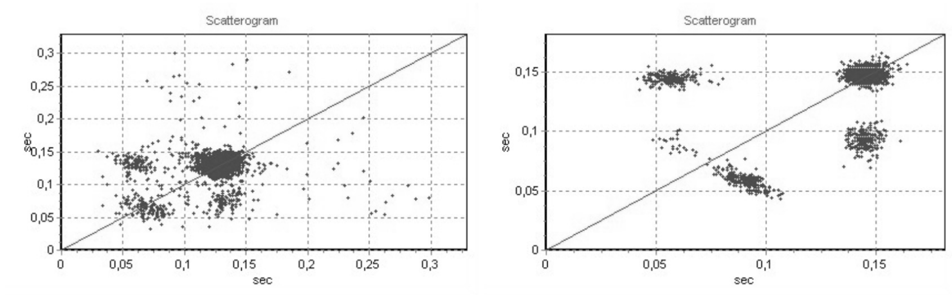

Fig. 2. Correlation rhythmogrammes (scatterogrammes) in hemic hypoxia in high- and low resistant animals

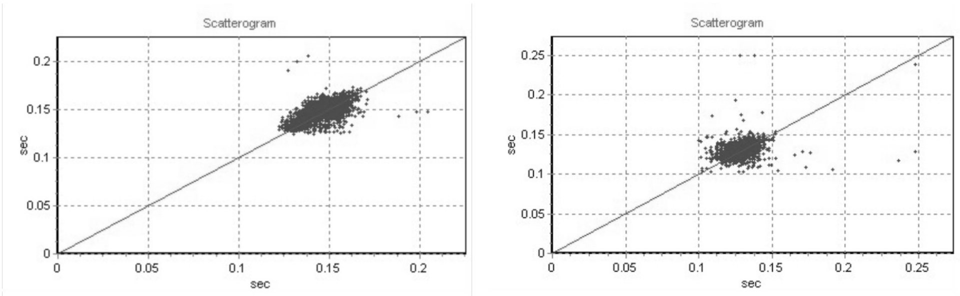

Fig. 3. Correlation rhythmogrammes (scatterogrammes) in hemic hypoxia in high- and low resistant animals which were exposed to interval hypoxic training and sodium nitrite injection

CONCLUSIONS

The obtained results confirmed that animals with different resistance to hypoxia under injection of nitro compound differed in separate parameters of regulatory systems of the functional activity. The positive effect of interval hypoxic trainings under conditions of experiment were revealed. Previous IHT application allowed to prevent functional overactivation of experimental animals' organisms under conditions of nitrite induced hemic hypoxia.

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REFERENCES

1. Aimasheva N. P. et al.: Nitric oxides as the factor antihypoxic effect of adaptation to an exercise stress. Proceedings of Sciences Academy by Russian Federation. Biology Series, 5, 634, 1997.
2. Baevsky R. M., Berseneva A. P.: Estimation of adaptable opportunities of an organism and risk of development of diseases. Medicine Moscow, 1997.
3. Baevsky R. M. et al.: Meta-analyzed heart rate variability, exposure to geomagnetic storms, and the risk of ischemic heart disease. Scripta Medica, 70, 199, 1997.
4. Gulyaeva N. V. et al.: Interval hypoxic training prevents oxidative stress in striatum and locomotors disturbances in rat model of parkinsonism. In: Progress in Alzheimer's and

Parkinson's Diseases, ed. by Fisher et al., Plenum Press, New York 1998.
5. Hypoxia and specific features of reactivity. Edition by V. A. Berezovskiy, Kiev 1978.
6. Fazan R. Jr. et al.: Power spectra of arterial pressure and heart rate in streptozotocin-induced diabetes in rats. Journal of Hypertension, 17 (4), 489, 1999.
7. Reutov V. P. et al.: Cyclic transformations of nitric oxide in mammals. Nauka, Moscow 1997.
8. Reutov V. P.: A cycle of nitric oxide in mammalian organism. Successes of Biological Chemistry, 35, 189, 1995.
9. Reutov V. P. et al.: The nitric oxide cycle in mammals and nitrite reducing activity of heme-containing proteins. Vopr. Med. Khim., 40 (6), 31, 1994.
10. Sazontova T. G et al.: Comparative analysis of peroxidation and antioxidant enzymes activities in rat adapted to different regimes of normobaric hypoxia. Hyp. Med. J., 4, 4, 1994.

SUMMARY

Research of the functional activity of an organism's regulatory system under hemic hypoxia on the background of interval hypoxic training (IHT) with the application of heart rate variability (HRV) was carried out. It has been marked that rats with different resistance to hypoxia in the introduction of sodium nitrite differed in some parameters of activity as autonomic as central contour of heart function regulation. The revealed differences of HRV indexes under experiment conditions witness adaptogenic effect of course interval hypoxic training. Namely, prophylactic IHT application allowed to prevent functional overactivation of regulatory system in experimental animals under conditions of hemic hypoxia.

STRESZCZENIE

Przeprowadzono badania funkcjonalnej aktywności systemu regulacyjnego organizmu w warunkach hipoksji hemowej na podłożu interwałowego treningu hipoksemicznego. Stwierdzono, że szczury z różną odpornością na hipoksję po wprowadzeniu azotynu sodowego wykazywały różnice w niektórych parametrach aktywności autonomicznej i centralnej regulacji serca. Różnice we wskaźnikach HRV w warunkach eksperymentu świadczą o efekcie adaptacyjnym w przebiegu treningu hipoksemicznego. Profilaktyczne stosowanie interwałowego treningu hipoksemicznego pozwala chronić funkcjonalną nadaktywację systemu regulacyjnego u zwierząt doświadczalnych w warunkach hipoksji hemowej.