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ON THE PROBLEM OF THE CARDIOVASCULAR SYSTEM AND RESPIRATION COMPARATIVE ADAPTATION IN CHANGING CLIMATE-GEOGRAPHICAL REGION AND ACUTE INFECTIOUS DISEASE

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It is well known that the central regulatory mechanisms of the two most important functions: circulation and respiration, are closely interrelated. Outwardly this interrelation is manifested in the form of respiratory arrhythmia associated with simultaneous decrease or increase of the respiration and heart rate [1, 2].
As a rule, either the heart rhythm dynamics or the rate and character of respiration are analysed, while the problem of interrelation between these systems still remains practically unstudied.
In our opinion, assessment of separate parameters: heart and respiration rate, is not sufficiently efficient and, in case of performing the assessment for a short time period, might lead to contradictory results.
This particular circumstance was the one that called forth use of a new approach in this work involving assessment of degree of the heart and respiration rate synchronisation by means of using their ratio in the analysis of intensity and duration of re-adaptation processes in the same subject in two different situations.
In the first case, we studied the subject's organism adaptation processes after an inflammatory disease (sore throat) during a two-year period: 1989-1990. "Acute" form of the disease manifested itself in April 1989. Residence of the subject: St. Petersburg.
In the second case during the period from November 1994 to November 1996, the study was made in changing the climate-geographical region. Initial residence of the subject: St. Petersburg. In January-February 1995, he stayed at the Polar Station Kolba (Dickson Island) and then returned to St. Petersburg.
Thrice a day (in the morning, by day and in the evening) while resting the subject assessed with palpation his heart rate ***(HR)*** during one minute as well as respiration rate **(*RR*)** as a number of inspiration-expiration cycles during the same time period.
The parameters averaged for a day were used as the initial data for subsequent analysis.
Data processing was started with determining ***K*** coefficient for each day, the coefficient characterising heart rate/respiration rate ratio.
Using the ***HR*** and ***RR*** averaged data for each 3-month interval with a one-month shift these parameters were determined:

- the coefficient of correlation between them, and
- the heart rhythm tension parameter characterising the ***HR*** attracting properties [3].

Juxtaposition of variations of the parameters characterising the 1st and the 2nd cases of adaptation was performed by means of:

- superimposition of the obtained realisations onto each other, and
- matching of their "critical" points corresponding to the moment of the disease development and the last winter hut day prior to returning to St. Petersburg.

And for the variations of the ***K*** coefficients – as well by means of preliminary normalising their levels by the minimums that were assigned zero value, and the maximums that were assigned one unity, respectively.

Results of the study

In the Fig. 1, A, the dynamics of ***HR***, ***RR***, and their relations ***K*** (curves 1, 2, 3) in development of an acute infectious disease in the subject is presented. Here it is obvious that along with the start of the disease development the association between the ***HR*** and ***RR*** changes. Insignificant decrease of the ***HR*** and a stepped increase of the ***RR*** occured which led to a sharp drop of the parameter ***K*** level with its subsequent stabilisation. At the moment of a sharp exacerbation of the subject's condition when the body temperature rose up to 40°C, ***HR*** up to 98/min, ***RR*** up to 32 cycles per minute, the ***K*** level dropped suddenly to the lowest mark corresponding to the "critical" point noted with an asterisk.
In subsequent days of the disease development, simultaneous growth of the ***HR*** and ***RR*** with subsequent discontinuous drop of the RR led to as intensive growth of the ***K*** level (the first arrow upwards), after which – along with the ***RR*** growth – its reduction occurred (the second arrow downwards).

In about 11-12 months after start of the disease and following the 9th-10th month of its "acute" manifestation corresponding to the "critical" point, a noticeable rise of the ***K*** parameter average level occurred (the third arrow upwards) associated with the same sharp drop of the ***RR***, and then its stabilisation with a slight negative trend.

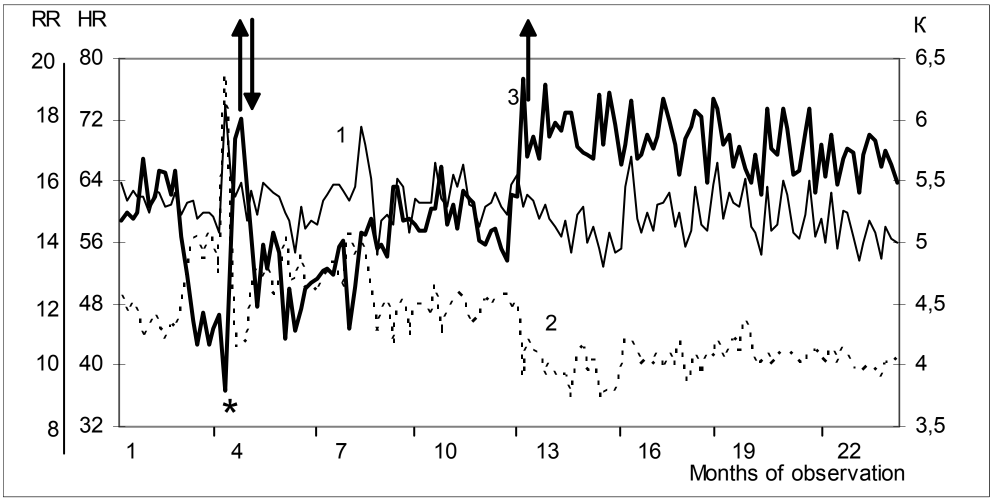

Fig. 1, A. The dynamics of the HR, RR, and their ratio in change of the functional condition due to acute inflammatory disease.

Designations: on the left ordinate axis – respiration rate (cycle/min) and heart rate (beats per minute); on the right ordinate axis – the K coefficient value = HR/RR; on the abscissa axis – months of observation. Curves: 1 (thin line) – change of the HR, 2 (dotted line) – RR, and 3 (thick line) – their ratio. The asterisk (*) marks the "critical" point characterising acute development of the disease.

In Fig. 1, B, the dynamics of the ***HR***, ***RR*** and their ratios ***K*** (curves 1, 2, 3) in change of climate-geographical region is presented. When the subject moves to northeast during the first month of the winter hut stay, gradual lowering of the ***K*** level occurs associated primarily with the ***HR*** drop. In the first days of the Sun disc appearance over the horizon, a more intensive lowering of the ***K*** occurs down to the minimum with subsequent abrupt transition to a higher level. During the second month, this parameter gradually decreases to the level that characterises the last day of the winter hut stay (the "critical" point on the curve 3 marked with the asterisk).

The return of the subject to St. Petersburg was accompanied by a considerable growth of the ***K*** parameter level (the first arrow upwards), which decreased again in a month time (the second arrow downwards).

A noticeable rise of the ***K*** parameter average level (the third arrow upwards) with subsequent stabilisation occurred in 10 months following the subject's return to St. Petersburg.

In the Fig. 2, A, the dynamics of the ***HR*** and ***RR*** correlation coefficients is presented: curve 1 – during the disease, curve 2 – on changing the climate-geographical region. It is evident that for the first case of adaptation (curve 1), in respect to the first interval including both the initial condition and the premorbid condition, the ***r*** between the ***HR*** and ***RR*** amounted to 0.4. With growing manifestation of the disease, the connection between the ***HR*** and ***RR*** was disturbed because of absence of synchronism of the rhythms, and the ***r*** became negative: -0.13.

Restoration of the ***r*** level to the established stable value 0.6-0.8 took 4-5 months from the beginning of the disease.

For the second case of adaptation (curve 2), in respect to the first interval including the subject's initial condition, the ***r*** between the ***HR*** and ***RR*** was 0.58. In change of the climate-geographical region associated with moving of the subject towards northeast (Dickson Island) and towards southwest, i.e. returning to St. Petersburg, and later on during one month, the ***r*** decreased but insignificantly. Desynchronising of the ***HR*** and ***RR*** rhythms occurred in the second month, the ***r*** dropping to 0.17. Restoration of the ***r*** level to the established stable value 0.6-0.8 took 6-7 months.

Fig. 2, B characterises dynamics of parameters of the heart activity tension in the described situations. In the initial condition, these parameters for the first and the second cases of adaptation amounted to 0.17 and 0.19, which corresponds to minor variability of the heart rhythm tension.

In the premorbid condition (curve 1), the tension variability increased, the parameter reaching the level of 0.53. In the period of "acute" manifestation of the disease (the "critical" point noted with the asterisk), the parameter altered its sign and became -0.42, which corresponds to arrhythmic tension. In 8-9 months after beginning of the disease, the parameter reached its maximal value 0.68 that signifies a high variable tension of heart activity. In 1 or 2 months after that its value became near zero. The restoration process of the initial value took 9-10 months.

While the subject stayed in polar region (curve 2), in the first days of the Sun disc appearance over the horizon line, the heart rhythm variability changed to arrhythmic one characterised by the minimal value of the parameter: -0.6. On returning of the subject to St. Petersburg, the value of the tension parameter noted with the asterisk remained the same: -0.6.

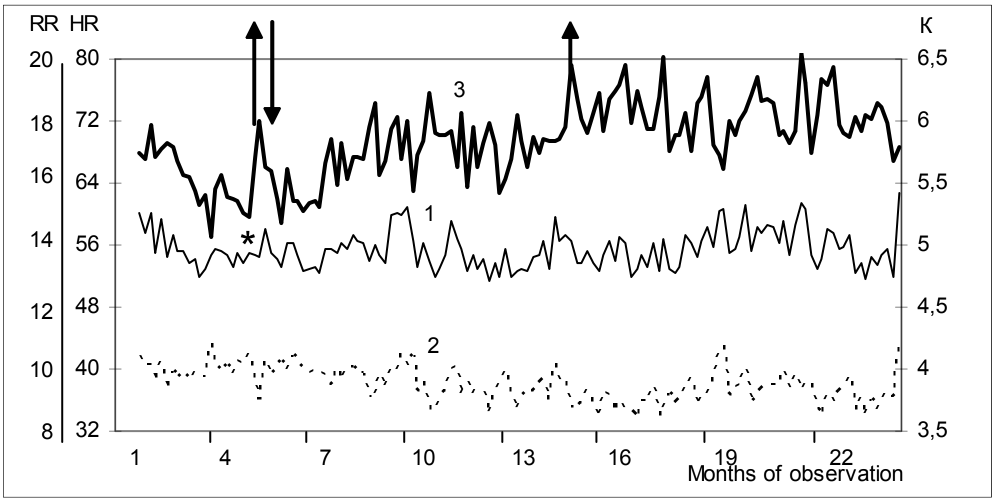

Fig. 1, B. Dynamics of the HR, RR and their ratio levels in change of the functional condition when changing the climate-geographical region.

The asterisk (*) marks the "critical" point characterising abrupt (within 24 hours) move of the subject from northeast (Dickson Island) to southwest (St. Petersburg).

Designations are the same as in Fig. 1**,** A.

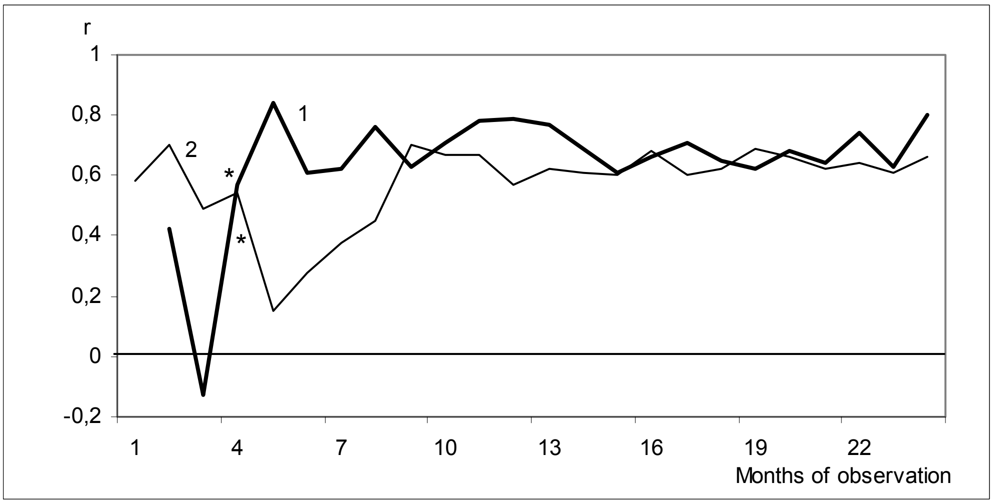

Fig. 2, A. Joint change of the correlation coefficient levels (r) of the HR and RR in the course of adaptation during the disease (1) and in change of the climate-geographical region (2) after superposition of the "critical" points (*).

In 3-4 months the parameter reached its maximal value 0.62 that determined a high level of the tension variability. Afterwards, in 1 or 2 months, its value was near zero. The restoration process of the initial value took 8 months.

Fig. 3 is an expressive illustration of the similarity of the processes under consideration, the Figure presenting normalized parameters of the ***HR*** and ***RR*** ratios (curves 1 and 2) following the superposition of the "critical" points. The character of the curve changes was the same, the ***r*** between them being 0.62.

Within 3 or 4 months, the parameter reached its maximal value 0.62 that determined a high level of the variable tension. Afterwards, in 1 or 2 months, its value was near zero. The restoration process of the initial value took 8 months.

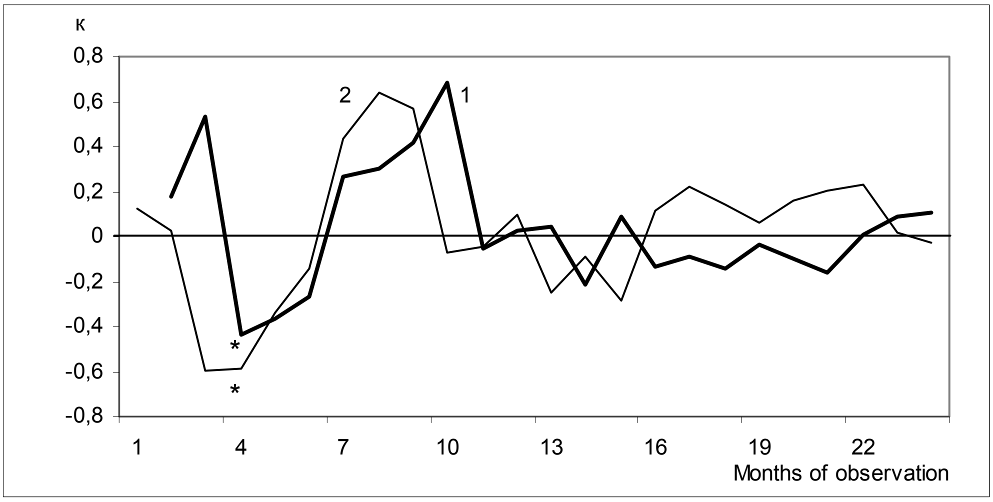

Fig. 2, B. Joint change of parameters of the heart activity tension (k) in the course of adaption during the disease (1) and in change of the climate – geographical region (2) after superposition of the "critical" points (*).

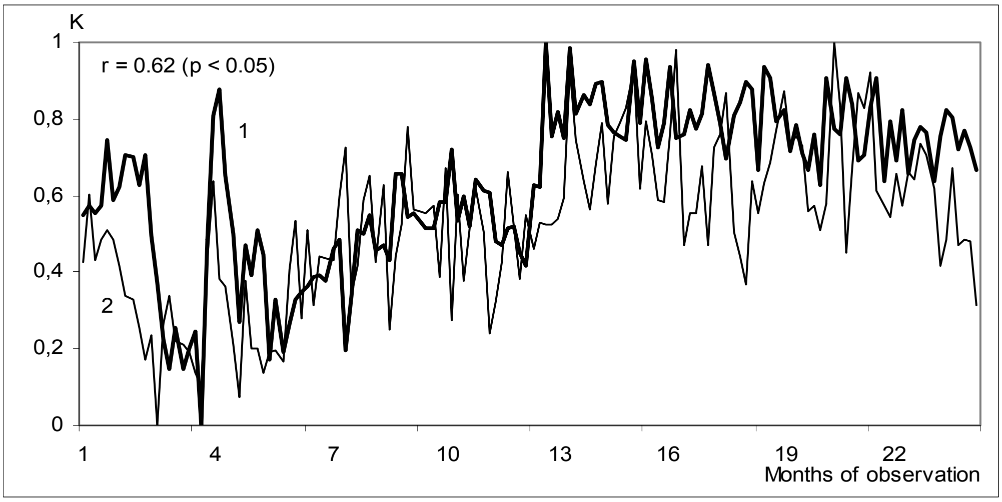

Fig. 3. Joint change of normalized levels of the HR and RR relations in the course of adaptation during the disease (curve 1) and in change of the climate-geographical region (2) after superposition of the "critical" points (*).

The analysis of the results shows that if in the first situation one case of adaptation breakdown was revealed, then in the second situation two breakdowns occurred confined either to appearance of the Sun disc over the horizon following one-month stay of the subject on the Dickson Island during the Polar night and, or to first days in St. Petersburg after cessation of the winter hut.

Analysis of dynamics of the heart rate, respiration rate and their relations ***K*** in adaptation to change of the climate-geographical region indicates that move of the subject to northeast leads to a rather smooth change of these parameters, whereas in the reverse move (to southwest: from the Dickson Island to St. Petersburg) the parameter ***K*** seems to be the most informative whose use made it possible to successfully reveal both breakdowns of the adaptation.

The cited facts suggest that the character of the re-adaptation to any stress effects, be it a disease, abrupt changes of the environment, etc., is based on common regularities aiming to development of the organism's optimal strategy of maintaining its homeostasis.

References:

1. Оранский И.Е., Царфис П.Г. Биоритмология и хронотерапия (хронобиология и хронобальнеофизиотерапия). М.: Высшая школа. 1989. 159 с.
2. Баевский Р.М. Прогнозирование состояний на грани нормы и патологии. М.: Медицина, 1979. 295 с.
3. Иванов В.В., Костыгова К.Н., Кузнецова Т.Г., Шуваев В.Т. Сердечный ритм шимпанзе при различных эмоциональных состояниях в процессе целенаправленной деятельности /Рос. физиол. журн. им. И.М.Сеченова. Т.88. №9, 2002, с.1225-1229.