EXPERIMENTAL BIOLOGY

Pattern of Individual Biorhythms of the Rectal Temperature of Rats in Health and during Starvation

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Individual cosinor-analysis with the use of special software demonstrates that the rectal temperature of intact rats exhibits two clear-cut rhythms: the circadian rhythm and a 96-h infradian rhythm. Under conditions of total starvation, including a lethal outcome, the spectrum of the biorhythms of the rectal temperature alters markedly: the circadian rhythm is completely eliminated in the majority of starving animals, the amplitude of the 4-day rhythm declines or this rhythm is also eliminated, and ultradian and infradian components appear in the biorhythmic pattern of the rectal temperature.

Key Words: *biorhythms of rectal temperature; starvation of rats*

Understanding how biorhythms with different periods (primarily circadian, ultradian, and infradian rhythms) are interrelated and interdependent is important in chronobiology, notably, in our view, for the biological assessment of the adaptive potential of biosystems, their functional reserves, reliability, and security.

Temperature homeostasis is the most suitable object for the use of such a chronobiological approach to studies of biosystems in light of the second law of thermodynamics and of the relationships between processes with or without changes of entropy. Despite the fact that measurements of the body temperature in patients were first introduced by Ludwig Traube in Berlin back in 1851, the practical importance of body temperature measurements is still limited.

Recently, more and more data are appearing in the literature providing evidence that the pattern of the diurnal rhythm of body temperature within normal physiological limits is a very informative index of the functional state of the organism.

We have established [2-4] that the parameters of the circadian rhythm of body temperature regularly change during the ontogenesis of mammals, including man.

Under conditions of starvation the entropy of a biosystem increases, the reserves of free energy diminish, and the functional systems become overloaded.

The aim of the present study was to characterize the pattern of the biorhythms of the rectal temperature in intact and starving rats using group and individual mathematical analysis, and in this way attempt to analyze the relationship between the circadian rhythm and ultradian and infradian rhythms.

MATERIALS AND METHODS

The experiments were carried out on 11 adult male rats in winter. All animals served as a control,

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after which they were used in the experiment. The study was performed in accordance with the following protocol: the rectal temperature of intact rats was measured daily with an electrothermometer every 3 hours (8 times a day) during 15 days. During this period, the rats received chow and water ad libitum and were kept in the laboratory under the natural (for the winter season) light-dark cycle. The animals were then subjected to total starvation, free access to water being provided. The rectal temperature was also measured daily 8 times a day until the animals died. Death occurred after 4-10 days of starvation. All results obtained by measurements of the rectal temperature of the rats in the control and experiment were processed using "Skazka" software, enabling individual cosinor-analysis to be performed and yielding data on the pattern of the biorhythms (from ultradian to infradian). Group analysis was also performed, which permitted the time course of the diurnal rectal temperature of rats to be followed-up daily throughout the course of the investigation.

RESULTS

Figure 1 shows that from day to day the rectal temperature of rats exhibits clear-cut fluctuations with a rhythm period of about 4 days. In intact rats this rhythm remains unchanged throughout the follow up. In starving animals such fluctuations of the rectal temperature are preserved, but they are attenuated.

In our opinion, the extinction of the week-long 4-day rhythms of the body temperature in starving rats is due to the increased entropy, a loss of order in the dissipative system (the living organism is such

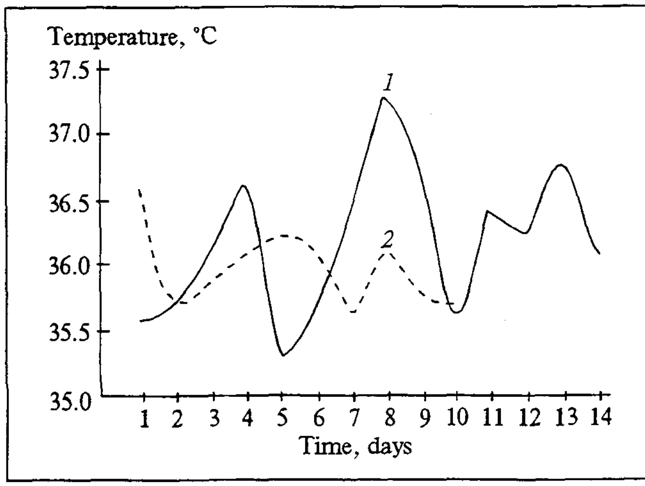

Fig. 1. Time course of mean diurnal rectal temperature of intact (*1*) and starving (*2*) rats.

a system), approaching thermodynamic equilibrium, and a loss of temporal and spatial synchronization of the mechanisms responsible for maintaining the optimal temperature homeostasis. The sharp peak of the rectal temperature in rats on the 1st day of starvation (Fig. 1) is of special interest. Probably, this is due to a considerable conversion of the primary heat (free energy) into secondary heat, which is promoted by the production of a cascade of hormones, including epinephrine and thyroxine, at the first stage of development of the general adaptive syndrome. The main results of individual cosinor-analysis are presented in Table 1.

Intact rats generally exhibit two rhythmic patterns of rectal temperature: a circadian rhythm and a 4-day (96-hour) rhythm. Judging by the amplitude, the 96-hour rhythm is, as a rule, more "powerful" than the circadian rhythm. In some intact rats 12- and 48-h rhythms are observed.

TABLE 1. Analysis of the Spectrum of Individual Biorhythms of the Rectal Temperature of Rats in Health and during Starvation

No. of rat	Period of rhythm, h		Mesor, °C		Amplitude, °C		Acrophase of circadian rhythms, h	
	control	experiment	control	experiment	control	experiment	control	experiment
1	20.6−12.2	28.8−96	36.32	36.06	0.46−0.39	0.54−0.35	19	
2	96−23.7	52.8−19.1	36.39	36.96	0.66−0.44	0.41−0.32	71	−
3	23.5	6.8−12.0	36.36	35.9	0.32	0.68−0.27	10.6	−
4	48−23.5	42−19.7	36.0	35.7	0.69−0.31	0.64−0.63	50	−
5	96−24.2	42−27.8	36.2	35.8	0.78−0.58	0.34−0.30	14.3	237
6	23.5−96		36.1	36.1	0.5−0.13	0.51	67	−
7	96−23.5	25.6−96	36.2	35.7	0.72−0.5	0.48−0.4	47	41.3
8	96−20.4	84−27.1	36.2	36.2	0.73−0.52	0.63−0.47	50	231
9	96−24	48	36.2	36.6	0.74−0.54	0.92	62	−
10	96−23.5−12	25.2−8	36.3	36.6	0.62−0.38−0.31	0.32−0.52	17.6	53
11	96−23.5	56.8	36.3	36.2	0.68−0.58	0.45	30.2	−

For the most part, the mean diurnal level (mesor) of the rectal temperature of rats ranges from 36.2 to 36.3°C, and the acrophases are observed at night.

Under conditions of total starvation the animals survived up to 4-10 days. Individual chronobiological analysis of the rectal temperature of rats throughout the period of starvation demonstrated that the rhythm spectrum of the rectal temperature exhibits marked changes: in 7 out of 11 rats the circadian biorhythm of the rectal temperature does not manifest itself; in rats which do preserve the circadian rhythm of temperature a reduction of the amplitude is noted. Mostly, the spectrum of rectal temperature biorhythms in starving rats is presented by new rhythms: a 8-19.7-h ultradian and a 48-84-h infradian rhythm. A multiple-day (4-day) rhythm of temperature homeostasis virtually disappears. A comparison of the chronobiological pattern of temperature homeostasis with the life span of a starving animal is worthy of interest. The rat presented in Table 1 as № 7 survived without food for 10 days, longer than any of the other rats. In this animal the rhythmic pattern of the temperature was the most stable: both the circadian and the multiple-day rhythms were preserved.

We may conclude that starvation leads to destabilization of the temporal organization of temperature homeostasis, in particular, to a change in the spectrum of the biorhythms and their parameters (mesors, amplitudes, and acrophases). Basing ourselves on previous experimental and clinical studies [1,5-8] and on the findings of the present investigation, we regard the circadian temporal pattern as a fine integral index of the stability of biosystems and of the degree of elimination of the optimal state after exposure to a stress factor (for example, starvation) in diseases and functional overload.

Deformation of the circadian temporal pattern may be assessed by analyzing a particular system of homeostasis (in practice temperature homeostasis is undoubtedly the most suitable). Deformation should be assessed not only as a change in the mesors, amplitudes, and acrophases, but also as a change in the spectrum of biorhythms and their "strength." The deeper we delve into the notion of "the optimal temporal pattern" or "the degree of health," the more important we find to be the role played by the circadian rhythms and the circadian temporal organization.

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