EFFECT OF MUSCULAR EXERTION ON CIRCADIAN RHYTHMS OF ADRENOCORTICAL ACTIVITY IN RATS

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The effect of muscular exertion (swimming for 1 h) at different times of the 24-h period on circadian rhythms of the 17-hydroxycorticosteroid concentration in the adrenals and peripheral blood of rats was studied. The results were processed on a computer by the "Cosinor" program. Physical exertion in the period of maximal motor activity of the rats (the evening) led to desynchronization of the circadian rhythms of the 11-hydroxycorticosteroid concentration in the adrenals and peripheral blood. Exertion during the period of minimal motor activity (the morning) had no such action.
KEY WORDS: muscular exertion; 11-hydroxycorticosteroids; circadian rhythms.

The maintenance of definite time relations between the 24-h dynamics of bodily functions is essential to the maintenance of homeostasis and resistance of the organism [1, 5, 6]. The circadian rhythm of adrenocortical activity, with which the resistance of the body is largely linked, depends chiefly in man on a number of social factors, but in crepuscular animals, on the conditions of external illumination [8, 9]. There is considerable information in the literature on the connection between adrenocortical function and muscular activity [2-4], but the possible influence of muscular exertion on the circadian rhythms of activity of this gland has not been analyzed.

The paper describes the results of a study of the effect of muscular exertion at different times of day on the dynamics of the corticosterone concentration in the adrenal tissue and blood plasma of albino rats.

EXPERIMENTAL METHOD

Experiments were carried out from October through December on 160 noninbred albino rats of both sexes weighing 100-150 g. The animals were made to undergo muscular exertion, in the form of swimming for 1 h, during the period of minimal (8-9 a.m.) and maximal (8-9 p.m.) motor activity.

To study the circadian rhythms of the adrenals, the experimental and control animals were decapitated every 6 h for 24 h after exertion.

The adrenocortical activity was assessed from the concentration of 11-hydroxycorticosteroids (11-HCS) in the peripheral blood plasma and adrenals [10]. The results were processed on a computer by the "Cosinor" porgram [7], with slight modifications to suit the experimental method. According to this program the real circadian rhythm is simulated by a cosine curve. This approach greatly facilitates the description of the rhythm and yields statistical characteristics of the circadian acrophase, which cannot be done if the data are treated by the usual methods of variance analysis.

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TABLE 1. Effect of Muscular Exertion on Circadian Rhythm of 11-HCS Concentration in Rat Adrenals (in mg/g). Results of Analysis by "Cosinor" Program

Group of animals	Mean level C_0	Circadian amplitude* (C_1)	Circadian acrophase	
			deg.	h
Control	8,6±1,9	2,9 (0,4—5,6)	—130 (from —80 to —200)	8:40 a.m.
Experimental exertion at 9 a.m.	5,2±1,4	1,3 (0,7—2,0)	—254 (from —150 to —290)	5:00 p.m.
Experimental exertion at 9 p.m.	4,3±0,4*	0,9 (0,2—1,5)	—310 (from —40 to 150)*	8:40 p.m.

*Here and in Table 2, 95% confidence interval.

TABLE 2. Effect of Muscular Exertion on Circadian Rhythm of 11-HCS Concentration in the Blood Plasma of Rats (in g %). Results of Analysis by the "Cosinor" Program

Group of animals	Mean level (C_0)	Circadian amplitude* (C_1)	Circadian acrophase	
			deg.	h
Control	7,6±0,7	1,3 (0,7—2,4)	—167 from-100 to —185)	11:00 a.m.
Experimental exertion at 9 a.m.	8,7±1,4	2,2 (0,5—3,7)	—150 from-125 to —270)	10:00 a.m.
exertion at 9 p.m.	11,7±2,3*	3,6 (1,6—5,5)	—255 from-245 to —260)*	5:00 p.m.

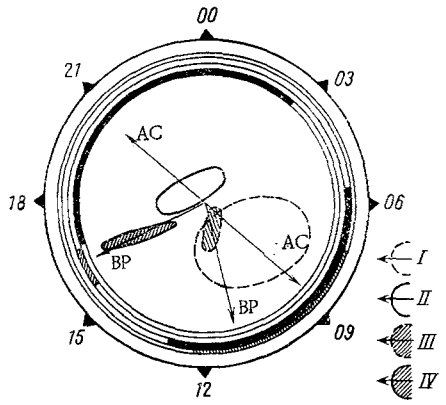

Fig. 1. Circadian rhythms of 11-HCS concentration in adrenals (AC) and peripheral blood plasma (BP) of control rats and after physical exertion at 9 p.m. (graphic representation of data processed by the "Cosinor" program). I and III) 11-HCS concentration in control rats in AC and BP, respectively; II and IV) 11-HCS concentration in rats after exertion in AC and BP, respectively.

EXPERIMENTAL RESULTS AND DISCUSSION

Concentration of 11-HCS in the Adrenals. In the autumn-winter period the circadian acrophase of the 11-HCS concentration in the adrenals of intact rats occurred at 8.40 a.m. (Table 1). A single exertion at the time of minimal motor activity (8-9 a.m.) led to a slight decrease in the mean 11-HCS concentration in the gland. In the experimental animals the amplitude of the circadian waves was reduced and the acrophase occured at -254° (from -150 to -290°), equivalent to 5 p.m. However, calculation of the ellipse of error when simulating the rhythm by a cosine curve (95% confidence interval) showed no significant shift of the acrophase in time compared with the control rats.

After swimming for 20-21 h, i.e., in the period of maximal motor activity of the rats, a statistically significant decrease in the mean 11-HCS level in the adrenal tissue was observed. The acrophase of the rhythm occured at -310° (from -40 to +150°), corresponding in the time to 8.40 p.m., i.e., the maximum of the 11-HCS concentration was in the opposite phase to the control.

11-HCS Concentration in the Blood Plasma. In the rats of the control group the acrophase of the circadian rhythm of 11-HCS occurred at 11 a.m. (Table 2). Physical exertion at 9 a.m. increased the amplitude of the circadian fluctuations of the blood 11-HCS level but had no significant effect on the acrophase. Swimming at 8-9 p.m. significantly increased the mean concentration and the amplitude of the circadian rhythm of 11-HCS in the blood plasma. The acrophase of the 11-HCS rhythm in the blood plasma was shifted through 88° compared with the control.

In the intact animals the acrophases of the circadian rhythms of the 11-HCS concentration in the adrenals and blood plasma were relatively synchronized (Fig. 1). The close similarity between the rhythms

of these parameters reflects their functional interconnection. After swimming at 9 a.m. the differences in the acrophases of 11-HCS in the adrenals and peripheral blood plasma did not reach the limits of significance. After swimming at 8-9 p.m. a significant difference was observed between the acrophases of these parameters. The appearance of temporal desynchronization between the 11-HCS concentration in the adrenals and peripheral blood may possibly reflect changes in the metabolism and excretion of the hormones, on which their final concentration in the peripheral blood largely depends.

The results are evidence that rats are most sensitive to physical exertion in the period of maximal motor activity, when it induces a well-marked afterresponse manifested as desynchronization of the circadian rhythms of two adrenal functions.

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