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Day-Night Changes After Exercise in Body Temperatures and Heart Rates of Hamsters[1]

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Abstract. A day-night rhythm of body temperature in the golden hamster (*Mesocricetus auratus*) is described, showing a maximum of about 37.6°C in the night-animal and a minimum which is about 1.3°C lower in the day-animal. The day-night difference is still present after forced exercise, indicating that the temperature-regulating mechanism, rather than muscular activity alone, accounts in part for the observed day-night rhythm of body temperature in the hamster. A day-night rhythm of heart rate was also found with a resting midnight level of 457 beats/min, and a resting noon minimum level which is about 45 beats/min lower. Apparently the hamster has a day-night cardiovascular setting as found in many other mammals. The heart rates decreased after forced exercise, and there was no evidence of the day-night heart rhythm during the period of recovery which extended for several hours.

Basal or resting core temperatures and heart rates of many laboratory and captive mammals have been recorded (Spector, 1956), but the literature contains few records of these measurements for the hamster. Because this animal is widely used in pharmacological investigations, the present study on the basal or resting measurements of this species appeared useful. The hamster is a hibernator and some animals of this type have a labile body temperature in warm environments (Johnson, 1928). These experiments were originally designed to establish the day-night rhythm of body temperature and heart rate in the hamster, on the supposition that a wide daily range might be found. Low values represent resting measurements. More importantly, consideration was also given to the importance of muscular activity in accounting for the observed daily rhythm of body temperature and heart rate.

Materals And Methods

Rectal Temperatures

The rectal temperatures of 15 male and 14 female adult hamsters (Series I) were recorded four times a day at 7 a.m., 12 noon, 5 p.m. and 11 p.m. during a 5-day period (ambient temperature 25±1 °C). On the basis of these results the effect of exercise (Series II) was studied only twice each day, at 12 noon and 11 p.m. Temperatures were measured by copper-constantan thermocouple in a metal-tipped rubber catheter, and a Ru-

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bicon potentiometer with a limit of error of 0.005 millivolts. The thermocouple consistently registered 0.4°C lower than mercury thermometers in a water bath from 35° to 40°C. All data are adjusted to the mercury reading. Each animal was held in a celluloid cone during temperature measurements, and since the procedure required no more than 1.5 minutes there was no significant warming effect by heat from the hand. After each series had begun the animals did not struggle during the temperature determinations. During these and all subsequent rectal temperature determinations, reproducible results were obtained by inserting the thermocouple 3 or 4 centimeters.

The effect of exercise on body temperature (Series II) was studied each day at 12 noon and 11 p.m. for a 3-day period (ambient temperature 27±1 °C). At these times each animal was subjected to periods of forced activity (10 revolutions in an activity wheel) followed by rectal temperature measurements. When alternating periods of exercise and temperature masurement gave three readings which checked within 0.1°C, it was assumed that exercise had exerted its maximum effect in increasing body temperature. The number of revolutions required was either 40 or 50. During the entire study food consisted of Rockland rat pellets and grain, and the light source from Tungsten light bulbs was controlled to prevent a seasonal change in activity. The data for both (1) the 5-day series on the day-night rhythm of body temperature and (2) the 3-day series on the effect of exercise on body temperature were analyzed statistically by the Wilcoxon Test. This test is a non-parametric method with no assumption of normalcy. Analyses which are cited in this report yielded "t" values between 2.0 and 3.0 corresponding to "p" values of 0.05 and 0.0013. A "p" value 0.05 means these results would be obtained by chance about 5 times in 100 trials, expressed as "significant at the 5% level". A detailed description of the application of this test to physiological work is given by Wilcoxon (1949).

Heart Rates

Heart rates were measured at noon and midnight before and after exercise (Series A, B). In this experiment the exercise consisted of having the animals swim to exhaustion in a plastic pail containing water at body temperature (36±1°C). This method was used because forcing the animals to run in a wire activity wheel was often a slow process because they clung to the wheel. A pilot swim-test on 29 hamsters showed: eleven individuals swam one hour or less; three over one hour; five over two hours; seven over three hours; two over four hours; and one swam five hours and 41 minutes. For the final experiment it was decided to swim each animal for one hour.

Heart rates were recorded with a Burdick Electrocardiograph. The usual difficulties were experienced in connecting a small animal to a large instrument. Standardized electrodes and connecting prongs were designed and used successfully not only with hamsters but with rabbits and cats as well. The EKG leads were fastened into a plastic box; connected into the box by banana plugs were flexible wires terminating in prongs obtained from the bases of vacuum tubes (Figure 1). The prongs

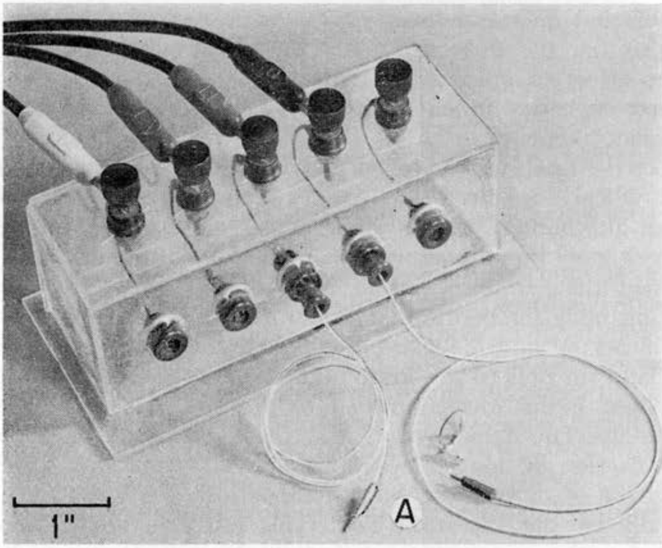

Figure 1. Plastic box connecting EKG leads to flexible wire leads. A: vacuum tube prong.

connected to individual sockets obtained from the plugs for vacuum tubes (Figure 2, *left*). The sockets were attached to two types of electrodes—either wound-clips with flexible wire leading to the sockets (Figure 2, *left*) or tantalum rings pressure-fastened to the sockets with rough edges covered with resin (Figure 2, *right*). These ring electrodes were placed under the skin of the animals a week or more in advance where they healed in place and remained without irritation for a year or more. The wound clips were frequently placed in position at the time of the experiment. In all experiments there were two electrodes, one over the left scapula and one over the right head-of-femur.

All heart rates were measured with the hamsters in a plastic yoke just tight enough to prevent the animals from twisting. After the first ten minutes the animals were quiet, and so both the control and experimental measurements consisted of the

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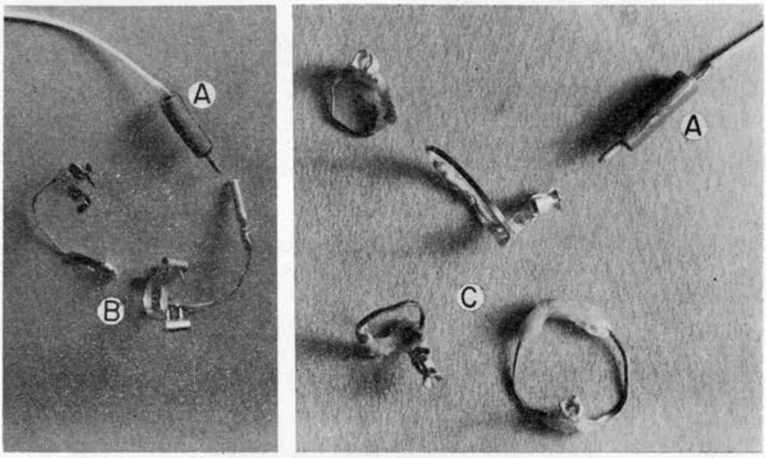

Figure 2. (Left) Wound clips connected to individual vacuum tube sockets (B). Note vacuum tube prong (A). (Right) Tantalum rings pressure-fastened to vacuum tube sockets (C).

mean of heart rates recorded at 10, 15, 20, and 25 minutes after the start of the measurements (see Figure 3, before swim).

Results

Rectal Temperature Measurements

A distinct day-night rhythm in body temperature of the hamster was found (Series I). The presence of this rhythm was reported earlier but no data were given (Folk and Schellinger, 1954; Folk, 1957). New information now presented is the observation that this rhythm was retained after exercise at noon and midnight (Series II). The day-night rhythm was confirmed by Chaudhry et al. (1958). Few data have been presented before on daytime resting body temperatures of the adult hamster (a hibernator), so that available figures in °C are now compared:

Table 1

Number of Animals	Males	Females	Source
15	38.7° (sex not indicated)		Chen, Powell, Maze, 1945
29	36.3°	36.4°	Folk and Schellinger, 1954 Folk, 1957
8	. . .	36.3°	Dean and Lyman, 1954
55	35.4°	36.2°	Chaudhry et al., 1958

In the series presented by Folk (1957) the lowest daily reading (which presumably represents basal or resting body temperatures) was consistently recorded during 5 consecutive days at 12 noon (Table 2). Why Chaudhry recorded lower temperatures (which were taken at 1 p.m.) is not known. At least the differ-

Table 2. Day-Night Changes in Rectal Temperatures of Male Hamsters (N = 15) (Series I)

A. Measurement in °C four times daily (means of 15 males)

Experimental Day	7 AM	12 N	5 PM	11 PM
1	37.1	36.4	36.8	37.8
2	37.1	36.2	36.8	37.1
3	37.4	36.0	36.3	37.7
4	37.1	36.6	35.8	37.7
5	37.2	36.2	36.3	37.4

B. Complete data for day 5 only (°C)

Animal No.	7 AM	12 N	5 PM	11 PM
23	37.9	36.5	36.6	37.6
24	37.4	36.2	35.9	38.2
27	37.7	36.0	36.2	37.5
30	37.2	36.4	37.1	37.5
35	37.5	35.7	36.8	37.3
37	37.9	36.8	36.6	37.8
38	37.5	35.7	35.9	37.6
41	37.2	36.6	35.4	38.1
42	35.9	36.6	36.3	37.2
43	35.7	35.5	36.5	37.0
44	37.2	36.6	36.0	37.1
45	37.4	36.2	36.7	37.6
46	37.4	36.0	36.1	36.2
48	37.7	35.7	36.0	37.5
49	36.0	36.6	35.9	36.8
Mean	37.2	36.2	36.3	37.4

ence between males and females is consistent. In the present series (partly illustrated in Table 2) the differences between noon and midnight temperatures were highly significant (11 p.m. males 37.5°C; females 37.7°C). The mean daily range for all days was 1.4 C for males and 1.3°C for females. The largest fluctuation occurred in the males, which for one day showed a mean range of 1.9°C between the low value of 35.8°C recorded at 5 p.m. and the peak of 37.7°C recorded at 11 p.m. The largest individual fluctuations recorded for a single day were 2.1°C for one male and 2.0°C for a female.

Temperature Rhythm Retained after Exercise

Forced activity was used over a 3-day period to elucidate the cause of the observed day-night rhythm (Series II). The rectal temperatures could not be made to reach as high a level by forced activity at noon as at midnight. Yet the increase due to exercise for males was 1.6°C at noon and 0.8°C at 11 p.m.; for females it was 1.9°C at noon and 1.0°C at 11 p.m. The body temperatures after exercise were:

TABLE 3

	Males	Females
Noon	38.4°C	38.5°C
	p value 1%	p value 5%
Midnight	38.7°C	38.8°C

Detailed results are presented for one of the three experimental days (Table 4).

Table 4. Rectal Temperatures (°C) for Day 3 Only for Males Exercised at Noon and Midnight (Series II)

	Time: 12 N		Time: 11 PM	
Animal No.	Before Exercise	After Exercise	Before Exercise	After Exercise
23	36.8	37.9	38.0	38.5
24	36.5	38.3	37.9	38.5
27	36.5	38.4	38.4	39.0
30	36.8	38.1	37.5	38.5
35	36.5	37.9	37.5	38.3
37	36.4	38.0	37.5	38.4
38	36.9	38.6	38.5	38.9
42	36.4	38.1	38.2	38.8
44	36.6	38.2	38.4	38.5
45	36.3	38.5	37.9	39.1
46	36.9	38.0	38.1	38.6
48	37.2	38.2	37.4	38.4
49	37.0	38.4	38.6	39.0
50	36.5	38.4	38.2	38.7
53	36.8	38.4	38.2	38.4
58	37.1	38.8	38.0	39.0
Mean (3 days) (males)	36.8	38.4	37.9	38.7
Mean (3 day) (females)	36.6	38.5	37.8	38.8

Day-Night Rhythm of Heart Rate

There was a consistent difference in heart rates of the hamsters when compared at noon and midnight. Male hamsters were studied on three consecutive days at midnight and noon (Series A, N=17). Mean resting heart rates in beats/min were: day 1, midnight 469, noon 448 (not sig.); day 2, midnight 468, noon 404 (p=0.1%); day 3, midnight 433, noon 385 (p=2%). Combined means were: midnight 457 beats/min; noon 412 beats/min.

Heart-Rate Rhythm after Exercise

The measurements of hamster heart rates after exercise (Series B) were dominated by unexpected results. Eighteen animals were exercised by swimming. During recovery, in every animal except one, after the first 10 minutes the heart rates dropped (instead of increased) by a percent which varied from 4% to 23%. The effect lasted for several hours (Figure 3) but the next day the heart rates of the hamsters had returned to normal. The day-night heart rate rhythm was obscured by this effect. Night-hamsters with a high heart-rate setting (423 beats/min) had a greater drop in heart rate than did day-hamsters

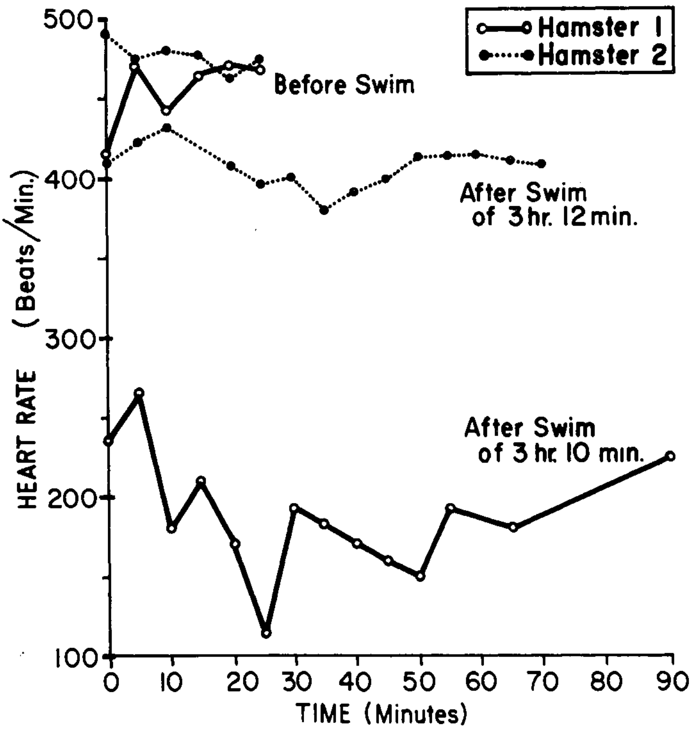

Figure 3. Heart rate of female hamsters before and after forced exercise.

(Figure 4). We have no explanation for this post-exercise effect upon the heart rate and the heart-rate rhythm.

Discussion

The mean resting body temperature of the hamsters used in this study lies within the range of resting temperatures of other mammals of comparable size, and the daily range of temperature is less than would be expected in hibernators. The mean resting temperature of male and female hamsters, 36.4°C, is consistent with this animal's size relative to other laboratory rodents, since the resting temperature reported for the mouse is 36.5°C, for the rat, 37.5°C, and for the guinea pig, 38-39°C (compiled by Rodbard, 1953), and for the rabbit, 38-39.5°C (Folk et al., 1957). However, Morrison presents evidence that no consistent correlation exists between weight and body temperature (Morrison and Ryser, 1952).

Fluctuations have been observed in the body temperatures of hibernators in warm environments (Johnson, 1928). The term heterotherm has been applied to hibernators and other mammals which show this wide fluctuation in body temperature (Hock, 1951). At room temperature two animals which hibernate, the ground squirrel and woodchuck, show considerable lability of body temperature. This range of variation (35.4°C to 39.2°C) is presented and discussed by Hock (1951). Johnson (1928) considered the fluctuation in the case of the ground squirrel to be due in part to the animal's "rather poorly adjusted heat-regulating mechanism." Since the hamster is also a hibernator the same lability of body temperature might occur. However, the greatest range in mean temperature noted on one day was 1.9°C, well within the range predicted for strictly homothermal animals (Kliteman, 1939).

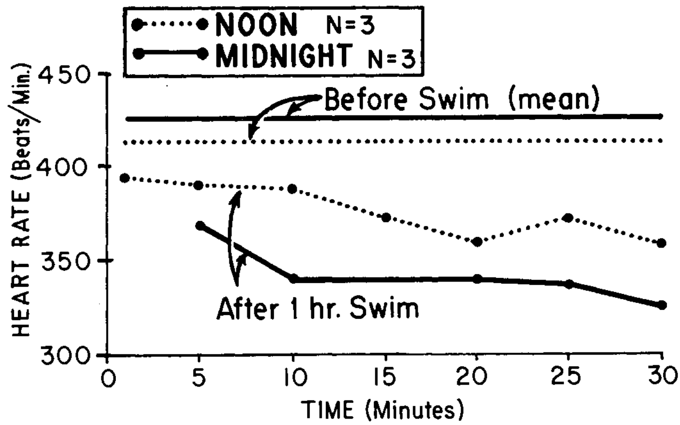

Figure 4. Heart rates of male hamsters after forced exercise at noon and midnight (N=3).

Day-night rhythms of body temperature in mammals including man have been reviewed by Kliteman (1939), and frequent observations that daily peaks in body temperature and muscular activity often occur simultaneously suggest that this activity accounts for the cyclic rise in temperature. In an early report, Simpson and Galbraith (1906) suggested that a setting in the temperature regulating mechanism accounts in part for the day-night temperature rhythm of monkeys. In the part of the present study in which hamsters were exercised, if increased muscular activity alone caused the peak in the temperature cycle then body temperatures should have been nearly the same after exercise at noon and midnight. The fact that there was a significant difference in body temperature after exercise supports the view that the temperature regulating mechanism rather than muscular activity accounts in part for the day-night rhythm of body temperature in the hamster.

The day-night rhythm of heart rate in the hamster, as measured in this experiment, could not be attributed to a sleepy or relaxed state of the day-animal when the recording was done at noon, because the process of placing the animal in the plastic yoke results in struggle and an excitement which lasts for about 10 minutes. Apparently the hamster, like the cat (Essler et al., 1961), has a day-night cardiovascular setting which results in a higher resting heart rate at night. It was not possible to test this setting with exercise as was done in the case of the hamster temperature rhythm, but this has been done in human experiments (Timmerman et al., 1959). The day-night rhythm or settings in body temperature and heart rate described in this paper may be under the control of the same physiological mechanism (possibly the hypothalamus) or two different mechanisms. Such a mechanism has been called a "biological clock" in the past, but current concepts have caused the term to be changed to "synchronizer". This new term attaches more meaning and more intricate function to the mechanism which controls each day-night physiological rhythm.

Bibliography

Chaudhry, A. P., Halberg, F., Keenan, C. E., Harner, R. N., and Bittner, J. J. 1958. J. Appl. Physiol. 12:221-225.

Chen, K. K., Powell, C. E., and Maze, N. 1945. J. Pharm. and Exp. Ther. 85:348-355.

Deane, H. W., and Lyman, C. P. 1954. Endocrinology 55:300-315.

Essler, W. O., Folk, G. E., Jr., and Adamson, G. E. 1961. Fed. Proc. 20: 129.

Folk, G. E., Jr., and Schellinger, R. R. 1954. Anat. Rec. 120:787.

Folk, G. E., Jr. 1957. Amer. Nat. 91:153-166.

Folk, G. E., Jr., Dodge, C. H., and Folk, M. A. 1957. Proc. Anim. Care Panel 7:253-258.

Hock, R. J. 1951. Biol. Bull. 101:289-299.

Johnson, G. E. 1928, J. Exp. Zool. 50:15-30.

Kliteman, N. 1939. Sleep and wakefulness. Chicago: University of Chicago Press.

Morrison, P. R., and Ryser, F. A. 1952. Science 116:231.

Rodbard, S. 1953. Science 117:256-257.

Simpson, S. and Gailbraith, J. J. 1906. Trans. Roy. Soc. Edin. XLV: 65-104.

Spector, W. S., Ed. 1956, Handbook of Biological Data. Saunders, Philadelphia, 584 pp.

Timmerman, J. C., Folk, G. E. Jr., and Horvath, S. M. 1959. Quart. Jour. of Exp. Physiol. XLIV: 258-263.

Wilcoxon, F. 1949. Some rapid approximate statistical procedures. Stanford: American Cyanamid Co.