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Analysis of Locomotor Activity and Body Temperature Rhythms in the Process of Daily Torpor in Djungarian Hamsters (*Phodopus sungorus*)

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Abstract: Djungarian hamsters show distinct seasonal rhythms in several physiological parameters. One of them is daily torpor that occurs in winter with decreased body temperature (about 10-20℃) during daytime. Daily torpor is induced by short-day photoperiod, food restriction and castration. But the mechanism to induce daily torpor has not been clarified. In the present study, we tried to clarify the process of daily torpor induction in detail. Adult male hamsters were kept in long photoperiod and high temperature (LP-HT) before the experiment and, thereafter, the animals were transferred to short photoperiod and low temperature (SP-LT), and they were kept in this condition for about six months. The daily rhythms of locomotor activity and body temperature were recorded every three-minutes by using the Minimitter telemetry system. Locomotor activity and body temperature showed very closely synchronized rhythms. All animals under LP-HT showed daily rhythms with higher locomotor activity and body temperature in nighttime than in daytime. Under SP-LT, there were two types of animals with and without showing daily torpor. Thus, they have individual differences in the response to SP-LT.

Key words: daily torpor, locomotor activity, body temperature, seasonal rhythms, circadian rhythms, ultradian rhythms

INTRODUCTION

The Djungarian hamster (*Phodopus sungorus*) shows distinct seasonal rhythms in several physiological parameters [1, 2]. Body weight and testis size decrease from fall to winter and increase from spring to summer. Food intake increases from fall to winter and decreases from spring to summer. Pelage color changes from brown to white in winter. And daily torpor occurs in winter. Daily torpor is the phenomenon in that body temperature reduces more than 10℃ to become torpid state daily [3]. Hibernating animals set up continuous hibernation (bout) and arousal (periodic arousal) alternately during hibernation and the longest record of the bout in 39 species of hibernation animals is different from 4-45 days. Daily torpor shows bout and periodic arousal daily [4].

Daily torpor may be adaptitation to winter for small mammals to reduce their daily energy expenditure. In some species, torpor can be facultatively induced by food restriction and moderate cold exposure [5]. However, in strictly photoperiodic species like the Djungarian hamster, torpor occurs only after several weeks of exposure to a short-day photoperiod and cannot be provoked by cold exposure and/or moderate food restriction. When maintained in short photoperiods, Djungarian hamsters may enter torpor regularly during their circadian resting period, even when kept at thermoneutrality and fed *ad lib* [6, 7]. Thus they display torpor spontaneously without any acute shortage of energy supplies and spontaneously reduce their daily energy expenses [8-10].

In the present study, we measured locomotor activity and body temperature rhythms and compared the differences between torpid animals and non-torpid animals.

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MATERIALS AND METHODS

Twenty-three adult male Djungarian hamsters, *Phodopus sungorus*, (about three months old) were used. Hamsters were housed singly in plastic cages (25 × 20 × 20cm) in which food and water were given *ad-lib*. Before the experiment, animals were maintained in long-day photoperiod and high temperature (16L8D; 16 h light and 8 h darkness, light on: 8:00-24:00, 20℃). After three weeks, a telemetry (MiniMitter, model XM-FH) was implanted into the abdominal cavity of the animals. After the surgery, animals were allowed to recover for 4 days and then they were transferred to short-day photoperiod and low temperature (8L16D, light on: 10:00-18:00, 10℃). The exchange of the battery of telemetry was done once in two months. Locomotor activity and body temperature were recorded every three-minutes by using the telemetry system. Body weight and food intake were measured once a week for about six months. Circadian and ultradian rhythms were analyzed by power spectra.

RESULTS

'Non-torpid animal' means the animal that did not show torpor throughout the experimental period. 'Torpid animal' means the animal that showed torpor. 'Torpid day' means the day when the torpid animals showed daily torpor. 'Non-torpid day' means the day when the torpid animals did not show daily torpor after daily torpor occurred.

In torpid animals, body weight began to decrease after the animals were transferred from LP-HT to SP-LT. It became significantly low after 8th week as compared with that at the beginning of experiment ($p<0.05$). On the other hand, it did not change significantly in non-torpid animals. Food intake increased from 0 to 4 weeks after transferred to SP-LT in both groups. In torpid animals, food intake was decreased from 13 to 18 weeks because of daily torpor. But non-torpid animals did not decrease the food intake and maintained the high level.

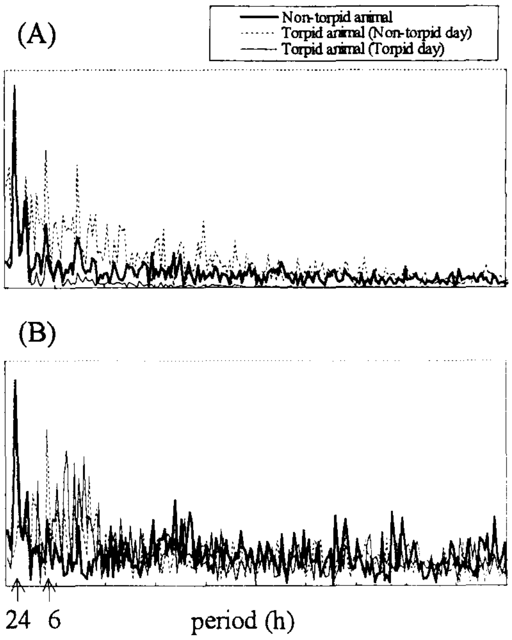

Figure 1. Examples of power spectra of body temperature (A) and locomotor activity (B) in SP-LT. The non-torpid animal (bold line, animal No.1) showed circadian component with 24 hour period. The torpid animal (narrow line and dotted line, animal No.5) showed ultradian rhythms with less than 6 hour period.

Table 1. Circadian and ultradian rhythms of non-torpid and torpid animals.

			Body temperature		Locomotor activity	
			24h	< 6h	24h	< 6h
Non-torpid animal		No.1	O	–	O	–
		No.2	O	–	O	–
		No.3	O	–	O	–
Torpid animal	Torpid day	No.4	O	–	O	O
		No.5	O	–	O	O
		No.6	O	–	O	O
	Non-torpid day	No.4	O	O	O	O
		No.5	O	O	–	O
		No.6	O	O	–	O

No.1-3 are non-torpid animals.
No.4-6 are torpid animals.

(O) shows that the peak was found by power spectra analysis.
(–) shows that the peak was not found.

In LP-HT, torpid and non-torpid animals showed circadian rhythms in both locomotor activity and body temperature. In SP-LT, non-torpid animals kept circadian rhythms in both locomotor activity and body temperature rhythms (Table 1, Figure 1). But torpid animals showed ultradian rhythms in addition to circadian rhythms. Appearance of ultradian rhythms differed depending on torpid and non-torpid days and locomotor activity and body temperature.

DISCUSSION

The Djungarian hamster, *Phodopus sungorus*, exhibits body weight loss, gonadal regression, and changing pelage color from blown to white and daily torpor in short-day photoperiod [6, 11]. However, not all animals respond to short-day photoperiods. Thus, hamsters can be separated into photo-responsive and photo-non-responsive phenotypes [12]. In this study, only six animals showed body weight loss and expression of daily torpor. This result suggests that most hamsters we used are the photo-non-responsive type.

In cold ambient temperature, hamsters take a large amount of food for keeping their body temperature. In torpid animals, food intake was decreased from 13 to 18 weeks because of daily torpor. This result supported that daily torpor is to reduce their daily energy expenditure [10].

A recent study in four diurnal and four nocturnal small rodent species [13] showed that the daily rhythms of locomotor activity and body temperature were synchronaized and both rhythms have highly significant correlation. Our result also showed that the daily rhythms of body temperature and locomotor activity are very closely synchronized in LP-HT and in non-torpid animals in SP-LT. However, torpid animals in SP-LT were different. We found that torpid animals in SP-LT showed differences in expression of circadian and ultradian rhythms between locomotor activity and body temperature. We think that the differences are very characteristic and important for torpid animals.

REFERENCES

1. Masuda, A. and T. Oishi (1988) Effects of photoperiod and temperature on body weight, food intake, food storage, and pelage color in Djungarian hamster, *Phodopus sungorus*. *J. Exp. Zool.* 248, 133-139.

2. Heldmaier, G., S. Steinlechner, J. Rafael and P. Vsiansky (1982) Photoperiod and ambient temperature as environmental cues for seasonal thermogenic adaptation in the Djungarian hamster, *Phodopus sungorus*. *Int. J. Biometeorology* 26, 339-345.

3. Tucker, V. A. (1962) Diurnal torpidity in the California pocket mouse. *Science* 136, 380-381.

4. Geiser, F. and T. Ruf (1995) Hibernation versus daily torpor in mammals and birds: physiological variables and classification of torpor patterns. *Physiol. Zool.* 68, 935-966.

5. Tannenbaum, M. G. and E. B. Pivorun (1987) Differential effects of food restriction on the induction of daily torpor in *Peromyscus maniculatus* and *Peromyscus leucopus*. *J. Therm. Biol.* 12, 159-162.

6. Heldmaier, G. and S. Steinlechner (1981) Seasonal control of energy requirements for thermoregulation in the Djungarian hamster (*Phodopus sungorus*), living in natural photoperiod. *J. Comp. Physiol.* 142, 429-437.

7. Heldmaier, G. (1989) Photoperiod and thermoregulation in vertebrates: body temperature rhythms and thermogenic acclimation. *J. Biol. Rhythms* 4, 251-265.

8. Ruf, T. and G. Heldmaier (1992) Reduced locomotor activity following daily torpor in the Djungarian hamster: recovery from hypothermia? *Naturwissenschaften* 79, 574-575.

9. Ruf, T. and G. Heldmaier (1992) The impact of daily torpor on energy requirements in Djungarian hamster, *Phodopus sungorus*. *Physiol. Zool.* 65, 994-1010.

10. Heldmaier, G., M. Klingenspor, M. Werneyer, B. J. Lampi, S. P. J. Brooks and K. B. Storey (1999) Metabolic adjustments during daily torpor in the Djungarian hamster. *Am. J. Physiol.* 276, 896-906.

11. Hoffmann, K. (1973) The influence of photoperiod and melatonin on testis size, body weight, and pelage color in the Djungarian hamster (*Phodopus sungorus*). *J.Comp. Physiol.* 85, 267-282.

12. Puchalski, W. and G. R. Lynch (1986) Evidence for differences in the circadian organization of hamsters exposed to short-day photoperiod. *J. Comp. Physiol.* 159A, 7-11.

13. Refinetti, R. (1999) Relationship between the daily rhythms of locomotor activity and body temperature in eight mammalian species. *Am. J. Physiol.* 277, 1493-1500.