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THEFWOREGULATION AND RHYTHMICITY IN *ELIOMYS MELANURUS* FROM THE NEGEV HIGHLANDS, ISRAEL

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ABSTRACT – Oxygen consumption (VO_2) and body temperature (T_b) were measured in the Asian Garden Dormouse, *Eliomys melanurus,* from a population inhabiting the semi-arid steppe habitats of the Negev Highlands in Israel. Prior to measurements, the animals were acclimated for at least three weeks to an ambient temperature of 24°C with a photoperiod regime of 12L:12D. The results of this study reveal that the resting metabolic rates of this species are relatively low and that even at T_a=25°C they may enter daily periods of torpor which can save up to 65% of the average daily energy expenditure of a normothermic individual under the same conditions. The emergence from torpor is accompanied by an overshoot in VO_2. Both norinothermic dormice and those in torpor show a daily rhythm of VO_2 and T_b with a clear pattern of a nocturnal species.

Key words: *Eliomys*, Metabolic rates, Thermoregulation, Torpor, Daily rhythms, Semi-arid.

RIASSUNTO – *Termoregolazione e ritmicità di* Eliomys melanurus *della regione niontuosa del Negev, lsraele* – Il consumo di ossigeno (VO_2) e la temperatura corporea (T_b) Sono stati misurati nel topo quercino asiatico, *Eliomys melanurus*, proveniente da una popolazione che in lsraele abita ambienti steppici semi-aridi della regione montuosa del Negev. Prima delle misurazioni, gli animali sono stati acclimatati per almeno tre settimane ad una temperatura ambiente di 24°C con un fotoperiodo di 12L:12D. I risultati di questo studio rivelano che i tassi metabolici di questa specie in condizioni di riposo sono relativamente bassi e che anche a T_a=25°C possono entrare in periodi di torpore giornalieri che permettono di salvare fino al 65% del consumo medio energetico giornaliero di un individuo normotermico alle stesse condizioni. Il risveglio dal torpore e accompagnato da un aumento di VO_2. Sia i Mioxidi normotermici che quelli in torpore mostrano un ritmo giornaliero di VO_2 e T_b con un chiaro pattern tipico di una specie notturna.

Parole chiave: Israele, *Eliomys*, Fisiologia.

INTRODUCTION

The Asian Garden Dormouse, *Eliomys melanurus* Wagner, 1849, is distributed in Israel in the Negev Highlands (30°7'N., 34°6'E) and in Upper Galilee (but only at Tel Dan 33°2'N., 35°5'E) where this population is an extension of the population inhabiting the Golan-heights and Mount Hermon (Harrison & Bates, 1991). The phylogenetic relationships among the Mediterranean forms of the genus *Eliomys* as well as the two populations in Israel and an isolated population inhabiting the high mountains in Southern Sinai are under discussion (Filippucci et al., 1988 a; Filippucci et al., 1988 b; Filippucci, 1992).

The population of *E. melanurus* inhabiting the semi-arid steppe ecosystem in the Negev Highlands is adapted to a non-arboreal existence and the animals are exposed to long periods without rain. Although the temperature can be relatively high during the day in summer (above 30°C), it is relatively cool at night when the dormice are active. During winter it becomes very cold and ground temperature falls below 0°C. Dormice were trapped several times during winter when the ambient temperatures were close to 0°C and they were found inside the traps the next morning in a state of torpor with a body temperature of 12°C (personal unpublished observations).

"Mammalian dormancy, defined as a period of inactivity, spans a continuum of physiological states ranging from sleep to seasonal hibernation, and the energetic savings of each strongly depends on the level at which body temperature is regulated" (French, 1992). A variety of rodent species lower their metabolism by hibernation or daily torpor in order to overcome winter energy constraints. Recently, Ruf & Heldmaier (1992) investigated the relative influence of the depth and duration of torpor episodes on daily energy requirements. They showed that the Djungarian Hamster, *Phodopus sungorus*, could save about 20% of its daily energy expenditure through daily torpor episodes longer than 4 h.

Dormice *(E. melanurus)* from the Negev Highlands population seem to be very active during spring time from tlie beginning of March untill the beginning of June. During this period up to 14 individuals were captured in one night in certain localities, using 120 traps. In the other months of the year the number of trapped individuals is very low (Haim, unpublished data). Observations under controlled conditions in the laboratory reveal that they spend many hours of the day inside a nest in a dormancy position throughout the year. During winter time under the same ambient temperature and photoperiod regimes, they may remain inactive for a few consecutive days (Haim, unpublished data).

The thermoregulatory abilities of dormice of the genus *Eliomys* were studied in populations existing further to the north (Kayser, 1961). The aim of the present research was to study thermoregulatory abilities in a marginal population from a semi arid steppe habitat, which is exposed to asymmetrical seasonality and to compare the results with those of other dormice distributed in more mesic and cooler habitats.

MATERIALS AND METHODS

Animals

The study was carried out on three individuals (two females and one male). Prior to measurements the animals were acclimated to an ambient temperature of 24°C and a photoperiod regime of 12L:12D (Diurnal Growth Chamber - Forma Scientific) for at least three weeks. Each dormouse was kept separately in a cage, in which sawdust and cotton-wool were used for bedding. Plant-pots were provided for use as a resting place. The dormice were maintained on a mixed diet. Fresh fruits (apples, pears, oranges and melons) were served as a water and carbohydrate source while rat pellets, enriched with fresh meat and hard boiled eggs, provided proteins.

Oxygen consumption and Body temperature

Oxygen consumption (VO_2) was measured at various ambient temperatures, using an open-flow system (Depocas & Hart, 1957). Dried air (silica gel, TamRod) was pumped through the system at a rate of 600 ml/min. VO_2 was recorded for a period of 60 min after a 3 h acclimation period. Oxygen concentration of the dried excurrent air was determined on an Applied Electrochemistry, A3 oxygen analyzer and recorded continuously on a Tek-dyn 712 recorder. Measurements were carried out during day time in a metabolic chamber (volume of 1100 ml) submerged in a temperature regulated water bath (Neslab, 500) connected to a (Neslab Exocal) cooler.

Body (rectal) temperature (T_b) was measured after each exposure to a given ambient temperature (T,) by using a copper-constantan thermocouple connected to a Wescor (TH-65) digital thermometer. The thermocouple was inserted 3 cm into the rectum of the dormouse for a period of less than 30 sec.

Daily rhythms of' VO_2 arid T_b

The daily rhythm of VO_2 was measured over 72 h. The dormice were kept in a metabolic chamber (Volume 2500 ml) at a constant ambient temperature of 25°C with a photoperiod regime of 12L: 12D (lights were on between 07:00-19:00). The ambient temperature in the metabolic chamber was kept constant by regulating the water temperature in the water jacket, that surrounded the metabolic chamber. Oxygen concentration was determined by using the equipment and methods as above. Rat pellets, carrots and apples were put into the metabolic chamber at the beginning of measurements and cotton-wool was offered for bedding. The daily rhythm of T_b was not measured simultaneously with VO_2 in order not to disturb the tested dormice. T_b was measured over 48 h at 4 h intervals after measuring the daily rhythm of VO,. For this purpose the dormice were kept in their own cages inside the Diurnal growth Chamber (T_a=25°C, 12L:12D). Average Daily Energy Expenditure (ADEE) was calculated from the daily rhythm of VO,.

RESULTS

The points for VO_2 and T_b in Fig. 1, are given for each individual as the variations are very high. I-lowever, the lowest metabolic rate recorded for all three dormice was at T_a= 30°C. The value recorded is 0.49±0.09 mlO_2/g.h for a mean body mass of 89.5±12.3 g. The mean body temperature recorded at T_a=30°C was 37.4±0.5°C. At T_a=32°C all three dormice increased VO, values and this increase was accompanied by an increase in T_b and they were hyperthermic. At $T_a \leq 24$ "C the mice exhibited low metabolic rates which were accompanied by a decrease in T_b. Individual number 3 remained normothermic even at T_a=12°C. Individual number 1 showed low VO, and T_b values at $T_a \leq 24$°C and was in torpor for at least six hours during the day, Figs. 2 and 3.

The daily rhythms of VO_2 and T_b are also given separately for each dormouse (Figs. 2 and 3). From these results it appears that *E. melanurus* is a nocturnal species that decreases its VO_2 during the period in which its not active to only *30%* of the values recorded during activity (Fig. 2 **A** and B).

DISCUSSION

The population of the Asian Garden Dormouse *E. melanurus* in the Negev

Highlands in Israel is a marginal population existing in a habitat which is much more arid and has a lower food availability than those in which other populations of this species exist. Rodent species adapted to arid habitats have low resting metabolic rates, lower than those predicted from their body mass (Hart, 1971; Borut & Shkolnik, 1974; Haim, 1984; Haim & Izhaki, 1989). These low metabolic rates are presumably important under arid conditions as they reduce the required food intake and save on water loss. It was also assumed that the decrease in RMR contributes to an increase in life span which is considered to be a crucial adaptation for small sized desert mammals that under their natural conditions, may not reproduce in years in which there is no rainfall (Haim, 1987).

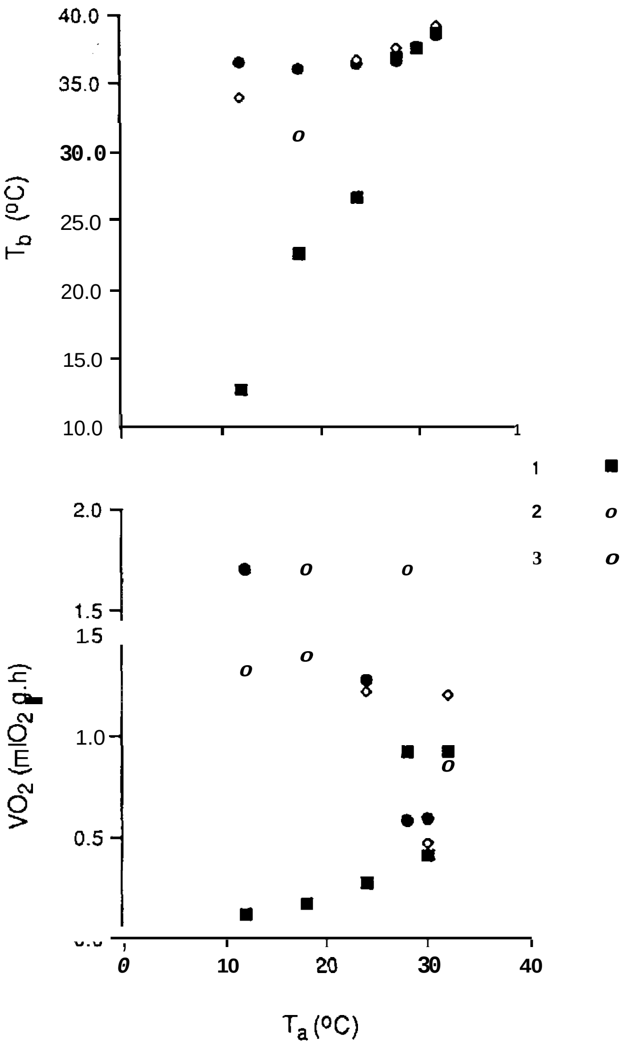

Fig 1 – Oxygen consumption VO_2 (mlO_2/g.h.) and body temperature T_b (ºC) of *Eliomys melanurus* at various ambient temperatures T_a (ºC). Each point represents the results measured for each individual.

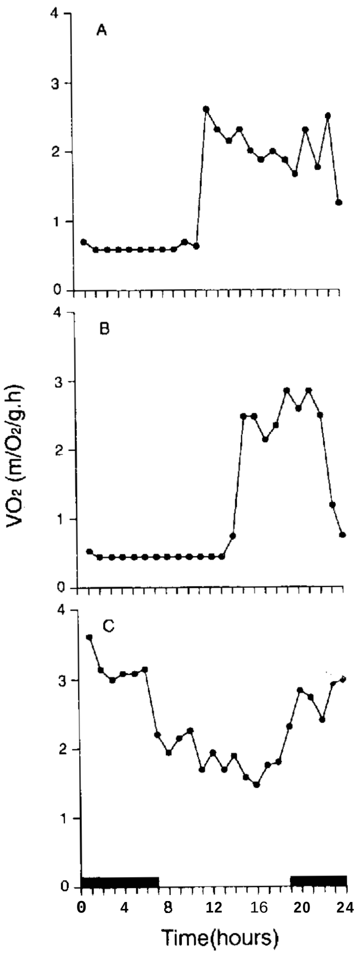

Fig. 2 – The daily rhythm of oxygen consumption VO_2 (mlO_2/g.h.) of *Eliomys melanurus* kept at an ambient temperature (T,) of 25°C with a photoperiod of 12L:12D, lights were on between 7:00 and 19:00h. **A** and B are measurements of torpid dormice while C is of a normothermic individual.

Low metabolic rates were also observed in the nonnothermic fat dormouse, *Myoxus glis*, (Gebczynski et al., 1972). At Ta=30°C, VO, measured in September - October in individuals of this species was 0.59±0.14 mlO_2/g.h., for a mean body mass of 151.7 g. The value recorded for *E. melanurus*, in our study is 0.49±0.09 mlO_2/g.h., for dormice with a body mass of only 89.5 g, which is about 59% lighterthan *Myoxus glis*.The results of this study show that the RM values of *E. melanurus* from the Negev Highlands are only 40% of that expected from their body mass according to allometric equations (Kleiber, 1961). In *M. glis*, the measured values are 55% of the expected for its body mass. Therefore it seems that RMR values are lower in *E. melanurus*. Such low values can significantly decrease the average daily energy expenditure (ADEE) of such rodents and may contribute to a reduction in water expenditure.

The ability to enter torpor even at a relatively high T_a in dormice of this population is of great interest. Recently, Ruf & Heldmaier (1992) have shown that in *Phodopus sungorus* torpor bouts reduced average daily metabolic rates by 17-21% when compared with normothermic hamsters. Comparing the average daily energy expenditure (ADEE) of individual number 1 which showed a torpor bout at T_a=25°C in this study with individual number 3, which was normothermic (Fig. 2), it can be seen that, due to torpor, individual number 1 saved about 65% of energy spent by the normothermic individual, number 3 (18.65 mlO_2/g.24h vs 52.2 mlO_2/g.24h). The higher percentage in daily energy saving when compared with the hamster may be due to the lower RMR of the dormice. However, the value of daily oxygen consumption in *M. glis*, measured at T_a=20°C during May - June is 40 mlO_2/g.day., for a body mass of 160.4 g, (Gebczynski *et al.* 1972). This result is similar to that obtained for the normothermic *E. melanurus*, (number 3j as the body mass of the latter was only 80g.

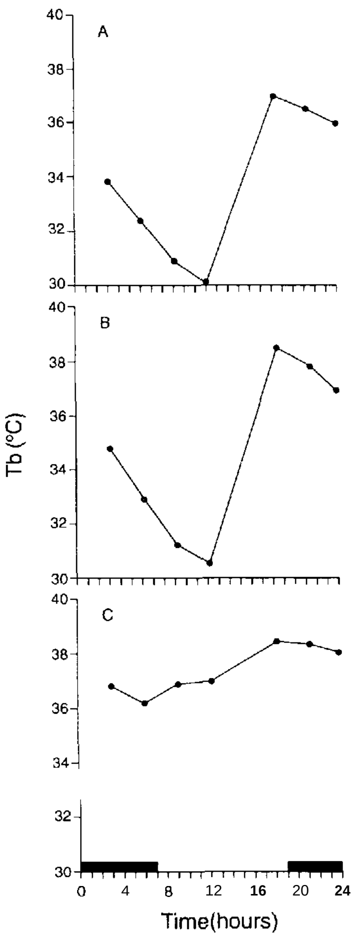

Fig. 3 – The daily rhythm of body temperature T_b ("C) of *Eliomys melanurus* kept at an ambient temperature (T_a) of 25°C with a photoperiod of 12L:12D, lights were on between 7:00 and 19:00h. A and B are measurements of torpid dormice and C of a normothermic individual.

Average daily energy expenditure **(ADEE)** was recently calculated for two species of murid rodents inhabiting two extremely different habitats in Israel. These were the golden spiny mouse *Acomys russatus*, which inhabits extremely hot and dry habitats in the Rift Valley and the Broad-toothed field mouse *Apodemus mystacinus*, which inhabits mesic habitats in the Mediterranean woodlands (Rubal et al., 1992). The values obtained for dormice numbers 1 and 2 (which were torpid) are similar to those of the desert species (1**8.65** mlO_2/g.day vs. 24.2 mlO_2/g.day). **As** the body mass of ***A.*** *russatus* is only 70 g and measurements were carried out at its lower critical point (T_a=33°C), these results are in good agreement. The results of the normothermic individual are in agreement with those obtained for the mesic species (52.2 mlO_2/g.24h vs 91.7 mlO_2/g.24h) as body mass of *A. mystacinus* was half the size of the dormouse and the dormouse was measuredat T_a=25°C while field mice were measured at the lower critical point, T_a=28°C. This comparison suggests that the normothermic dormouse has an ADEE similar to that of a mesic species, while in dormice with torpor bouts ADEE is similar to that of a desert species although under measuring conditions it is exposed to a mild ambient temperature of only 25°C.

Decrease in T, caused an increase in VO, of the normothermic *E. melanurus* and the value measured at T_a=12°C was 1.70 mlO_2/g.h. with a T_b of 36.5°C. This value is much lower than that recorded in *E. quercinus* (Kayser, 1961) which at T_a=7°C was 3.9 mlO_2/g.h. with T_b maintained at 38.1°C.This difference may suggest that the ability of normothermic *E. melanurus* to increase its heat production and maintain a high T_b (under the experimental acclimation conditions) is lower than in *E. quercinus*, from more mesic and cooler habitats.

Circadian rhythms of VO, were measured in *M. glis*, under controlled conditions of T_a=20°C and a photoperiod regime of 12L:12D (Gebczynski et al., 1972). Under these conditions two patterns of circadian rhythms are described, one for a normothermic fat dormouse and the other for a dormouse which underwent daily torpor. The patterns described in our study for normo-thermic *E. melunurus*, and for the individuals with daily torpor are similar to those of *M. glis*, with relatively similar values of VO_2.

The results of our study are the first physiological data to be published on *E. melanurus* from a semi-arid habitat. Their low meta-bolic rates and their ability to enter torpor even in relatively high ambient temperatures may partly explain the fact that their activity is relatively low and, therefore, apart from spring, they are trapped in very small numbers compared with other species which exist in the same habitat. Collecting more eco-physiological data on dormice from this population and carrying out further experiments using mani-pulation of environmenta l para-meters will be of great interest.

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