The oxygen consumption in growing Fat dormice, *Glis glis*

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Receipt of Ms. 17. 4. 1980

Abstract

Studied were oxygen consumption and body weight changes of Fat dormice during the first month of postnatal life. Seventeen dormice out of 5 litters, born under laboratory conditions, were measured. The animals showed a considerable increase of the metabolism level under cold stress at the end of the second week of life. Animals raised within whole litters attain the thermoregulatory capacity earlier than single individuals. Thermoregulatory mechanisms of *Glis glis* are more slowly developed in comparison to non-hibernating rodents.

Introduction

Examination has been made on the level of metabolism in adult hibernating mammals during the periods of decreased body temperature and during normothermy. Hibernators in their wakeful state have no lesser capacity for thermogenesis than non-hibernating mammals (Kalabukhov 1960; Kayser 1961). Data on metabolic response of hibernators to the cold during their postnatal growth are related to only one species (Hissa 1968). For the Fat dormouse, indirect conclusions to the development of such capacity can be drawn. On the fourth day of pastnatal life, the body temperature of Fat dormice in the nest was on average 32.5 °C (Gębczynski 1970), and in adult dormice it was 35.5 °C (Eisentraut 1956). Also rapidly increasing resistance to moderate cooling during the first weeks of life has been observed (Gębczyński 1970).

The purpose of the present study was to measure oxygen consumption of Fat dormice during the first month of life at different temperatures. Since the young animals remain in the nest, usually closely huddled together, measurements were made on both single individuals and on whole litters, and in this way the development rate of metabolic reactions was estimated for the Fat dormouse, so making possible a comparison with the rates specific in other rodents.

Material and methods

The Fat dormouse, *Glis glis* Linnaeus, 1758, is a small rodent leading an arboreal life. Young Fat dormice (average litter size – 4.5) are born blind and naked. So far, little has been discovered of their postnatal development. It is only known that the ears are opening on days 12–13, the eyes on days 20–23 post partum. Their fur has already developed on the 16th day, and weaning takes place at the end of the 6th week (König 1960; von Vietinghoff-Riesch 1960).

Fat dormice reproduce in captivity. Thus, measurements of oxygen consumption on growing animals became possible. Seventeen individuals out of 5 litters (litter size: 2, 3, 3, 4, 5) were investigated. The litters were kept in cages together with their mothers at a room temperature of 16–18 °C. Part of the cages were padded with hay, being used by the females as nest material for the newborn offspring.

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Z. Säugetierkunde 46 (1981) 289–295

ISSN 0044-3468 / InterCode: ZSAEA 7

For single individuals, oxygen consumption was measured in a closed-circuit respirometer with 1 l chamber, for whole litters (more than 20 days of age) a chamber with 9 l capacity was used. The measurements were carried out during the time span of 30 minutes, but took only 15 minutes for single individuals within the first 10 days of postnatal life. Measurements were not preceded by fasting of the animals. They were separated from their mothers, weighed and placed in a respirometer chamber. In some cases body temperature was taken additionally before and after measurements of oxygen consumption. Heat production was calculated from the amount of oxygen consumed, with the assumption that the respiratory quotient is = 0.9 and the calorific equivalent of O_2 is = 4.924 kcal/1 l.

Results and discussion

Body weight

There are few data on the body weight of *Glis glis* during the period of postnatal development (von Vietinghoff-Riesch 1960). Systematic weighings of young at the time of measuring oxygen consumption provided information on the rate of growth in the Fat dormouse (Fig. 1). The results obtained differ slightly from the data presented by von Vietinghoff-Riesch (1960) who reported for *Glis glis* a weight of 1–2 g on the first day of

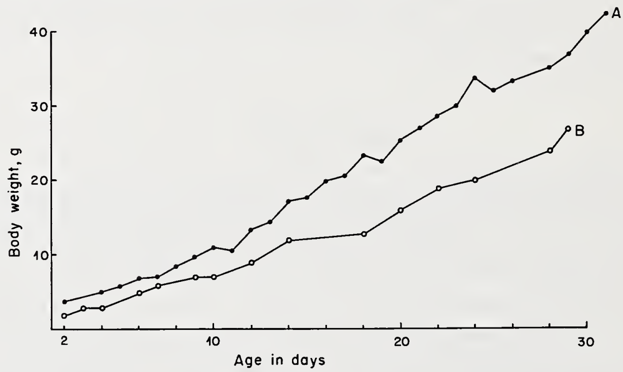

Fig. 1. Body weight changes in *Glis glis* during the first month of postnatal life. A: Author's data. Growth 2–11 days equals 0.91 g/day, 12–31 days equals 1.53 g/day; B: Data by von Vietinghoff-Riesch (1960). Growth = 2–11 days equals 0.50 g/day, 12–29 days equals 1.06 g/day

life. In our case, the body weight of newborn dormice was slightly more than 3 g, even in the litter consisting of 5 young. This litter was either born in the course of the evening or during the night, since inspection made in the afternoon did not indicate the start of parturition and when inspected in the morning of the following day (March 26), 5 young were found which weighed: 3.0, 3.2, 3.3, 3.3, 3.4 g.

The rate of body weight increase during the first postnatal month is not even, and amounts up to the 11th day on average to 0.9 g/day, but from the 12th to 31st day of life it increases to 1.5 g/day (Fig. 1). The data given by von Vietinghoff-Riesch (1960) also emphasize the uneven rate of growth in body weight, since for the same periods the respective figures are 0.5 and 1.1 g/day (Fig. 1). Differences in body weight increase may possibly be explained by the influence of the season. Von Vietinghoff-Riesch measured a litter born in September, while our studies concern litters born during the period from February to May. The same author refers to the fact that, generally, Fat dormice born in autumn do not attain their full weight until spring of the following year. This may be the same phenomenon as that observed in the bank vole, a non-hibernating rodent, whose young born in autumn are physiologically younger than those born in spring and growing more slowly (Fedyk 1974).

In hibernators juvenile growth is correlated with the duration of the homeothermal periods (KIELL and MILLAR 1977), that is also depending on seasonal differences.

Oxygen consumption by single individuals

Oxygen consumption of 2–29 days old animals was measured at ambient temperatures of 20° and 26–27 °C; two additional measurements were made at 15 °C. A temperature of 26–27° is the physiological cool zone, and although in adult fat dormice the minimal heat production occurs at 29 °C (KAYSER 1939), the thermoneutral zone is undoubtedly higher in the case of young still living in the nest. The fact, that the animals were not deprived of food before the measurements also indicates that the value obtained may be higher than the basal metabolic rate (BMR). It would, however, appear that the resting metabolic rate (RMR), to some degree, represents postnatal variations in BMR. RMR rapidly rises with increasing body weight up to about 15 g, attained by Fat dormice at the age of 12–15 days. In heavier, and consequently older animals, the increase of the metabolic level (Fig. 2) is abruptly slowing down.

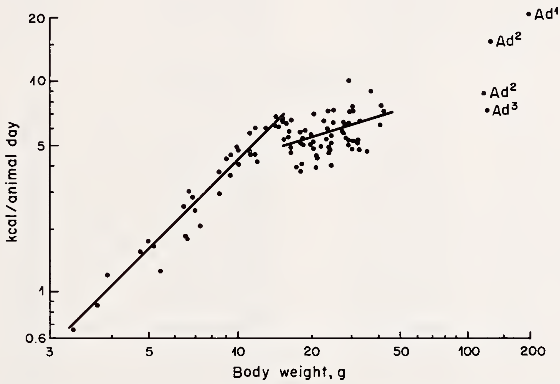

Fig. 2. Relationships between body weight and resting metabolism level at ambient temperature 26–27 °C in growing *Glis glis*. Body weight 3–15 g; $Y = -0.99 + 0.51 x$, $r = 0.96$, $n = 33$; body weight 16–42 g; $Y = 3.88 + 0.07 x$, $r = 0.39$, $n = 59$. Values for adult dormice: [1]BMR (after KAYSER 1939); [2]BMR (after KAYSER 1965); [3]RMR at 26 °C in the autumn (after GĘBCZYŃSKI et al. 1972); [4]ADMR at 30 °C in the autumn (after GĘBCZYŃSKI et al. 1972)

HISSA (1968) has drawn attention to the lack of a straight-line relation between BMR and body weight in the growing hibernator *Mesocricetus auratus*. These relations are also subject to variations in the development of nonhibernating rodents, for instance, in *Lemmus lemmus* (HISSA 1968) and in the rabbit (PIEKARZEWSKA 1977); they follow a curved line. Conversion of the results obtained in growing *Glis glis*, i.e. to metabolism/ body size ($kg^{0.75}$), as suggested by POCZOPKO (1979), revealed a rise in the level of metabolism up to the 12th day of life, followed by a decrease (Table 1).

At a temperature of 20 °C, however, Fat dormice exhibit a very low level of oxygen consumption during the first two weeks of life, and their body temperature fell according to measurements for about 3.2 °C. It is not before the animals reach the age of 15 days that the level of metabolism markedly rises, and stabilization does not take place until they are more than 3 weeks old, but even at the age of 26–30 days their thermoregulatory capacity has not yet fully developed. If we take RMR measured at 26–27 °C as a basis, then at 20° increase reaches 144 %, which means that oxygen consumption increases about 20 % per 1° decrease in ambient temperature. Similarly, the increase at 15° is 177 %, that is an index between 20° and 15 °C = 7 % : 1 °C.

Table 1

Metabolic rate of *Glis glis* during the first month of life at different ambient temperatures

The oxygen consumption measurements were taken with single individuals

Age, days	n	Body weight, g	$cc0_2$/g hr	kcal/animal day	kJ/kg $^{0.75}$ day
		Ambient temperature 15 °C			
17	2	20.9	3.45	8.52	651
29	6	35.1 ± 2.7	4.12 ± 0.45	17.09	871
		Ambient temperature 20 °C			
7	3	6.8	1.51	1.21	246
9	2	9.9	1.22	1.42	193
11	3	11.1	1.47	1.93	244
15	6	17.9 ± 1.3	2.69 ± 0.63	5.69	498
17	6	20.8 ± 1.2	3.11 ± 0.48	7.64	586
19	2	24.4	3.60	10.38	704
21	5	27.0 ± 0.9	3.34 ± 0.39	10.65	676
23	7	30.2 ± 2.1	3.86 ± 0.59	13.78	796
26	6	34.4 ± 1.0	3.62 ± 0.42	14.72	766
		Ambient temperature 26–27 °C			
2	3	3.6	2.02	0.88	361
4	4	5.1 ± 0.3	2.62 ± 0.43	1.56	426
6	6	6.7 ± 0.2	3.06 ± 0.60	2.41	502
8	6	8.7 ± 0.7	3.41 ± 0.67	3.52	520
10	8	11.0 ± 0.8	3.62 ± 0.47	4.68	593
12	8	13.9 ± 1.4	3.75 ± 0.29	6.12	643
14	12	17.2 ± 1.1	2.41 ± 0.42	4.87	437
16	10	20.0 ± 1.4	2.28 ± 0.55	5.27	416
18	10	23.4 ± 1.6	1.78 ± 0.23	4.90	343
20	9	26.1 ± 2.7	1.97 ± 0.36	6.00	391
22	10	28.8 ± 2.4	1.94 ± 0.48	6.57	395
25	4	32.7 ± 2.5	1.40 ± 0.27	5.36	289
30	6	39.9 ± 2.4	1.60 ± 0.32	7.46	347

In adult Fat dormice, the metabolic rate during spring and autumn is rising up to a peak of 10 %/1° at ambient temperature below 20°, and in autumn, between 20° and 26° it amounts to 6 %/1 °C (Gębczyński et al. 1972). Thus, although average body temperature in Fat dormice at the end of the first month of life, is the same as in adult individuals, their thermoregulatory system is, as mentioned above, still incomplete. This is manifested by considerable fluctuations in body temperature and more marked metabolic reactions to the cold. Despite the fact that Fat dormice are able, at the end of the second week of life, to achieve a considerable rise of the metabolism level under cold conditions, their thermal balance is not complete even in the fourth week of life. It must, therefore, be concluded that heat loss mechanisms develop more slowly than the mechanisms of heat production.

Oxygen consumption by litters

By huddling together in the nest, newborn dormice are more or less protected from excessive heat loss (Hull 1973), and suitable conditions ensured for rapid growth. If Fat dormice are kept singly, the rate of body temperature loss is quicker than in animals brought up in whole litters (Gębczyński 1970).

Oxygen consumption rate at 27 °C, expressed in cc/g h, increases about 80 % during the first 9 days of the animals' life, after which it decreases (Table 2). In the case of the 8 days old litter, consisting of 2 young, the metabolic rate was low despite the fact that the body

Table 2

Metabolic rate at different ambient temperatures in the litters of *Glis glis*, during the first month of animals' life

n indicates the number of oxygen consumption measurements

Age, days	n	Litter size	Litter weight, g	cc O_2/g hr	kcal/litter day	kJ/kg $^{0.75}$ day
			Ambient temperature 15 °C			
11	1	3	31.3	2.68	9.9	554
15	1	3	52.5	2.80	17.4	661
19	1	3	63.7	3.41	25.7	846
25	2	3	93.6	3.66	40.4	999
28	1	5	173.1	3.50	72.0	1124
31	2	2	88.9	3.78	39.7	1020
			Ambient temperature 20 °C			
16	2	2+3	49.9	2.40	14.1	567
19	2	2+3	64.8	2.75	21.1	683
25	1	2	62.4	2.53	18.6	610
26	1	2	66.9	2.53	20.0	636
29	2	2	74.4	2.25	19.8	580
			Ambient temperature 27 °C			
2	2	2+3	9.5	2.04	2.3	313
5	1	2	12.3	1.96	2.8	335
6	2	2+3	18.1	2.89	6.2	536
8	1	2	16.5	2.02	3.9	366
9	1	3	28.8	3.43	11.7	704
12	2	2+3	33.2	2.37	9.3	498
15	2	2+3	44.5	1.57	8.2	352
18	2	2+3	61.0	1.74	12.5	426
21	1	2	54.4	1.53	9.8	508
24	2	2	67.3	1.34	10.6	336
28	1	5	173.1	0.99	20.2	315
31	2	3	126.7	1.21	18.1	357

temperature of these two individuals was only 0.4° lower during the time of measurements than compared with Fat dormice of the same age.

At 20 °C Fat dormice, kept together, exhibit a fairly similar rate of oxygen consumption irrespective of age (16–29 days). At 15 °C, however, 11 and 15 days old litters are characterized by low metabolic level, and it is not until the age of 19–31 days is reached that this index is markedly higher (Table 2).

If the energy requirement is calculated (KJ/Kg$^{0.75}$ day) for litters of Fat dormice at the age of 24–31 days, it will be found that its increase after a drop in ambient temperature from 27° to 20° amounts to 11 %/1 °C, and between 20 and 15° amounts to 14 %/1°. By comparing these indices with those similarly calculated for single individuals, it becomes obvious that Fat dormice in litters resist the cooling effect of the environment far better than single animals. Not only do they maintain body temperature better (Gębczyński 1970), but loose less energy as well. Consequently, litters attain the capacity for homeometabolism earlier than might have concluded from measurements made on single individuals.

Hibernating versus non-hibernating rodents

Comparing the rate of body weight increase in hibernators, e.g. the golden hamster (Hissa 1968), *Spermophilus l. lateralis* (Clark and Skryja 1978) with that in non-hibernating rodents, this study on the Fat dormouse indicates a general similarity.

In both groups, the body weight increases tenfold during the first four weeks of life (see Handbook of Biological Data for non-hibernating rodents). Clark's claim made in 1970 that hibernators grow more quickly than non-hibernating rodents, thus, appears not applicable to all species.

Hissa (1968), in tracing postnatal development of the lemming and golden hamster, found that metabolic response to cold is more slowly advancing in hibernators. At 12° the hamster does not increase its oxygen consumption until it is 17–18 days old, and at 23° when 14–16 days old, while in the lemming this occurs at the age of 10–11 and 2–3 days respectively. In the Fat dormouse, development is similar to that in the hamster, although the former attains somewhat earlier the thermoregulatory capacity. This is undoubtedly connected with the slightly higher body weight of Fat dormice at the given age than that of hamsters. Comparison of data for the two species of hibernators with informations available on non-hibernating rodents (Hull 1973) shows that the thermoregulatory capacity does not develop uniformly. Thus, in hibernators, despite their similar increase of body weight to that of homeothermic animals, the heat production mechanism works later, and development of heat loss regulation fails to appear for still a longer time, and even in adult animals it seems to be insufficient (Kayser 1965). Therefore, it has to be concluded that the physiological functions, connected with heat production, and rather more important, heat loss, develop later in hibernators than in non-hibernating mammals of similar size.

Zusammenfassung

Altersabhängigkeit im Sauerstoffverbrauch bei jungen Siebenschläfern (Glis glis)

Der Sauerstoffverbrauch und die Zunahme des Körpergewichts im ersten Lebensmonat wurden an 17 in Gefangenschaft geborenen Siebenschläfern aus 5 Würfen untersucht. Bis zum Alter von zwei Wochen steigt der Sauerstoffverbrauch nach Kältebelastung beträchtlich. Im Gesamtwurf untersuchte Tiere erreichen die Fähigkeit zur Thermoregulation früher, als man aus Meßwerten von isoliert geprüften Tieren schließen würde. Bei *Glis glis* nimmt das Körpergewicht der Jungtiere ebenso rasch zu wie bei nichtwinterschlafenden Nagern, wogegen sich bei ihm die Fähigkeit zur Thermoregulation langsamer ausbildet.

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Food and habitat of badgers (*Meles meles* L.) on Monte Baldo, northern Italy

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Receipt of Ms. 19. 2. 1981

Abstract

Studied the food of European badgers *Meles meles* in northern Italy using faecal analysis, and vegetation and altitude used by badgers in different seasons. Both volume and frequency of occurrence of different foods were quantified; at all times of year, fruits, especially olives, were most important (62 % in volume), but earthworms, arthropods, gasteropods and various vertebrates were also taken. High altitude regions were used only in summer, probably to exploit earthworm populations; the low-lying olive zone was used at any time. The distribution of these resources was likely to determine the badgers' range sizes.

Introduction

This paper describes the food of badgers (*Meles meles* L.), as determined by faecal analysis, in a study area on the slopes of Monte Baldo, northern Italy; it also describes seasonal fluctuations in food and food availability, seasonal foraging at different altitudes, and the boundaries of badger territories.

The Monte Baldo area is biologically important because of its rich flora and fauna, and this badger study was prompted by the threat of road construction which would separate the lower slopes from the higher ones. This might affect the badgers which are numerous in the area. In addition, knowledge of the badgers' feeding ecology here is important for a comparison with studies in north-western Europe, where the species is usually a specialist feeder on earthworms (*Lumbricus* spp.; ANDERSEN 1955; SKOOG 1970; BRADBURY 1974; WIERTZ 1976; KRUUK 1978a; KRUUK and PARISH in press a) which are relatively uncommon in the Monte Baldo area. Earlier studies have discussed the relationship between the local distribution of the badgers' main food and their spatial organisation (KRUUK 1978a; KRUUK and PARISH in press b), and the Monte Baldo study area offered a chance to look at this relationship in a very different environment.

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Z. Säugetierkunde 46 (1981) 295–301

ISSN 0044-3468 / InterCode: ZSAEA 7