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Body Temperature and Oxygen Consumption in Growing Field Voles

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Body temperature (TB) of the field vole, *Microtus agrestis* (Linnaeus, 1761) is 32—33°C for 5 days after birth. Afterward, it gradually increases ($\bar{x}$=0.4°C/day) to attain 37.4°C by day 16. The TB of older voles is constant (37.7 — 38.0°C) until 20 months of life. Between days 6 and 16, increases of TB are accompanied by elevated oxygen consumption at 18°C ambient temperature. Between 21 and 26 days of life, however, oxygen consumption at 18°C decreases. Differences of oxygen consumption in the age groups examined are evidently smaller at 25°C ambient temperature and at 32°C they are negligible.

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1. INTRODUCTION

Body temperature of many homeothermic animal species is low during early postembryonic development and increases to the species-specific level at different rates. Body temperature incerases may proceed steadily or with variable degrees of acceleration (see literature review by Gębczyński, 1981a). Uneven rate of attainment of adult body temperature may reflect nonlinear dependency between metabolic level and body weight in growing animals. Heat production in *Rattus norvegicus* (Kleiber *et al.*, 1965), *Lemmus lemmus* (Hissa, 1968), and *Oryctolagus cuniculus* (Piekarzewska, 1977) increases rapidly early in life, then decreases. Poczopko (1969) suggested that the basic metabolic rate was unstable in growing homeotherms. This instability has, however, not been confirmed in all species, *e. g.*, *Microtus arvalis* (Bashenina, 1960) and *Mesocricetus auratus* (Piekarzewska, 1977). I am unaware of data allowing indirect evaluation of body temperature and metabolic rate in growing mammals. Therefore, this study addressed the comparison of those two parameters in *Microtus agrestis* during its early postnatal period. Subsequently, body temperature of voles as old as 20 months were measured to confirm T_B stability while aging.

2. MATERIALS AND METHODS

Data were recorded from 400 captive-bred and -reared voles at the Mammals Research Institute at Białowieża. Parents with litters were housed in cages (40×20×15 cm) with separate nest boxes. Cage floors were covered with forest duff and hay was supplied for nesting material.

Body temperature (T_B) was measured immediately after animals were removed from their nest between 0900 and 1100, using an electric thermometer (TE3 Elektro-laboratiet, Copenhagen, with H1 and F6 probes accurate to 0.1°C). See Gębczyński (1975) for other measurement details. Oxygen consumption was determined from 148 voles (none examined more than twice) during one-hour periods in a closed-type respirometer (chambers of 0.1, 0.2, or 0.5-1 according to animal size) (Górecki, 1968). Oxygen consumption rates were determined at 18°C, 25°C, and 32°C ambient temperature (T_A). T_A of 32°C is probably near the nest temperature of *Microtus agrestis* since their T_B is 32—33°C during the first 5 days after birth and heat generation is negligible (Chew & Spencer, 1967; Pichotka, 1971; Gębczyński, 1975). T_As of 18°C and 25°C are in the physiologically cool zone for neonatal rodents, but 25°C is thermoneutral for those with developed thermoregulation while 32°C is physiologically hot and 18°C stays in the sphere of coolness for them. Thus, O_2 consumption at 18°, 25°, and 32°C allows observation of age-dependent metabolic reactions in these rodents.

O_2 consumption rates were measured in voles of 4 age groups: 2-5 days old when T_B is lowest and nonfluctuating; 7-10 days and 13-16 days, respectively, when T_B begins to increase and stops increasing; and 21-26 days spanning the age at which field vole T_B fully stabilizes. Statistical differences among groups were determined by Student's *t* test.

3. RESULTS

3.1 Body Temperatures

T_B 1-5 days after birth (mean 32.1°C to 33.0°C) are about 5°C lower than in mature voles (Table 1). The relatively low variations of these values suggest that T_B of this species is relatively stable during the first few days of nest life. But during the subsequent 11 days, T_B increases an impressive 0.4°C per day, attaining 37.4°C by day 16 after birth.

T_B of 688 voles 17-630 days old was 37.7 ± 0.6°C. Thus, T_B stability achieved by 17 days persists for voles over one and one-half years old.

3.2 Oxygen Consumption Rate

O_2 consumption at T_A 18°C is lowest in voles 3-5 days old. Voles 7-10 days old consume twice as much as those aged 3-5 days but less than those aged 13-16 days. Thus O_2 consumption quadruples while T_B increases from 33 to 37°C (Table 2, Fig. 1). Voles 21-26 days old use

Table 1

Body temperature and weight in growing and adult *Microtus agrestis.*

Age in days	n	Body temp., Mean±SD		Body weight, g±SD	
1	18	32.7	1.2	2.1	0.3
2	16	33.0	0.7	2.5	0.3
3	26	32.1	0.6	2.8	0.4
4	17	32.5	0.5	3.1	0.5
5	21	32.8	0.6	3.6	0.2
6	25	33.6	1.4	4.0	0.4
7	27	34.1	1.3	4.4	0.5
8	23	34.6	0.9	4.7	0.5
9	28	35.2	1.2	5.1	0.3
10	21	35.1	1.1	5.6	0.8
11	22	35.3	1.8	6.2	0.9
12	26	35.4	1.3	6.4	1.7
13	25	35.7	1.0	6.7	0.6
14	28	36.2	1.3	7.6	1.5
15	30	36.8	0.8	8.2	0.8
16	27	37.4	0.9	8.9	1.1
17—18	37	37.7	0.5	9.4	1.7
19—20	50	37.1	1.7	10.3	1.8
21—22	42	37.5	1.2	10.6	2.0
23—30	123	37.7	0.6	12.9	3.1
31—90	127	38.0	1.0	—	
91—364	221	37.7	0.7	—	
365—630	88	37.6	0.6	—	

Table 2

Oxygen consumption rate in *Microtus agrestis* at different ambient temperatures of postnatal life.

Items	Age in days			
	2—5	7—10	13—16	21—26
	Ambient temperature 18°C			
n	28	22	30	16
Body wt., g	3.1	5.6	8.2	13.0
cc/g hr±SD	1.96±0.66	3.91±0.44	8.16±0.93	6.35±0.35
$kJ/kg^{0.75}$ day	348.6	628.2	1176.9	1075.3
	Ambient temperature 25°C			
n	20	23	12	25
Body wt., g	3.4	5.6	8.6	12.3
cc/g hr+SD	3.27±0.45	3.48±0.50	4.72±0.73	3.76±0.37
$kJ/kg^{0.75}$ day	558.1	558.9	693.7	629.6
	Ambient temperature 32°C			
n	25	17	12	21
Body wt., g	3.5	5.4	8.3	14.0
cc/g hr±SD	2.15±0.26	2.61±0.46	3.04±0.80	2.58±0.51
$kJ/kg^{0.75}$ day	362.7	419.3	440.5	435.1

less oxygen, than to those 13-16 days old. However, O_2 consumption rates are statistically different ($p<0.05$ or $p<0.01$) among all groups.

At T_A 25°C, O_2 consumption changes similarly as at 18°C but less significantly among age groups. Thus, voles 3-5 days old and those 7-10 days old differ less ($p<0.05$) in O_2 consumption than do those in the 13-16 vs. 7-10 day age groups ($p<0.01$). Accordingly, O_2 consumption rates at 21-26 days is significantly lower ($p<0.05$) than at 13-16 days.

At T_A 32°C, growing voles had age-dependent O_2 consumption rate differences but these were significant ($p<0.05$) only between groups 3-5 vs. 7-10 days of age.

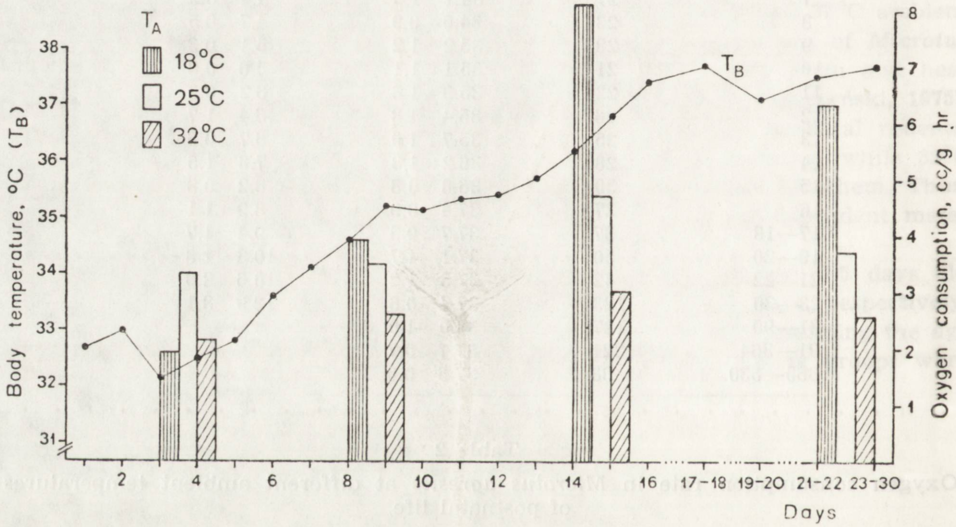

Fig. 1. Body temperature and oxygen consumption at different ambient temperature in *M. agrestis* during its first month of postnatal life.

Comparisons of metabolic rates in growing mammals are confused by body weight changes. Poczopko (1979) dealt with this by converting data into metabolic body sizes (kg $^{0.75}$). When this method is used to examine O_2 consumption rates for *M. agrestis*, it confirms the rapid rate increase concomitant with achievement of adult body temperature. Maximal O_2 consumption rates are most demonstrable when measured in the zone of physiologic coolness, where they are many times greater than in the thermoneutral zone (Table 2).

4. DISCUSSION

Nesting, neonatal rodents of all species examined to date have lower body temperatures (by 3-5°C) than do adults of the same species (Morrison *et al.*, 1954; Pichotka, 1971; Gębczyński, 1975, 1981a). Removal from the nest results in rapid T_B loss during the first few days of life, as has been demonstrated for *Microtus arvalis* (Bashenina, 1960), *Mus musculus* (Pichotka, 1971) and *Pitymys subterraneus* (Gębczyński, 1981a). Though T_B of adult *M. agrestis* in the nest is fairly constant (37.7 ± 0.6°C, this study), it is affected by T_A. Thus, *M. agrestis* T_B increases from 37.8°C at T_A 0°C to 38.9°C at T_A 30°C (Hansson & Grodziński, 1970).

Just after birth, young mammals experience different heat production rates than they subsequently do as adults reacting to decreased T_A. Field voles 2-5 days old consume oxygen significantly more so at 32°C than at 18°C. Conversely, by 13-16 days, they metabolically react to cooling such that a decrease of 1°C T_A results in a 19.1% increase in O_2 consumption rate. By 21-26 days the increase is 17.5%/1°C but still greater than for adults (10%/1°C) (Hansson & Grodziński, 1970; Ferns, 1979). Thus, nesting *M. agrestis* quickly develops heat generating capacity as a metabolic response against body cooling. This ability is most distinctly expressed when young voles attain body temperatures typical of adults (Fig. 1).

Such elevation in metabolic rate in growing mammals, both in their thermoneutral zone and as a response to cold, is known for many species (Kleiber *et al.*, 1965; Hissa, 1968; Piekarzewska, 1977) and suggests more rapid development of a heat production mechanism than one for regulating heat loss (Poczopko, 1961). It should be stressed, however, that measures of metabolic levels in growing mammals do not indicate fluctuating metabolic development in all species. This pattern of metabolism development is confirmed in *Microtus arvalis* (Bashenina, 1960) and *Mesocricetus auratus* (Piekarzewska, 1977) and is suggested for *Microtus agrestis* by the present study. Variable metabolism in *Mesocricetus auratus* seems related to variable embryonic development in this species, thus hampering study of metabolic ontogenesis under basal conditions. In growing rodents, the zone of thermoneutrality decreases, but more importantly, their body temperatures are lower than are those of adults. Lower T_B, in turn, markedly suppresses metabolism, especially as *M. agrestis* shows, in comparison with that experienced when T_B elevates during the next few days of life. It can therefore be assumed that ontogenetic metabolism levels of rats (Kleiber *et al.*, 1965), golden hamsters and lemmings (Hissa, 1968), and of rabbits (Piekarzewska, 1977) are inherently related to body temperature elevation mechanisms as they develop toward adulthood. These processes are demonstrated by the metabolic development of *Glis glis* (Gębczyński, 1981b). It may therefore be proposed that the nonlinear interdependence of metabolic level and body weight in growing rodents is related to establishment of adult body temperature.

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TEMPERATURA CIAŁA A TEMPO ZUŻYCIA TLENU U NORNIKA BUREGO W OKRESIE POSTNATALNYM

Streszczenie

U nornika burego, *Microtus agrestis* (Linneus, 1761) zmierzono temperaturę ciała zarówno w okresie rozwoju gniazdowego jak i u osobników starszych. W początkowych dniach po urodzeniu temperatura ciała młodszych korników przebywających w gnieździe wynosi 32—33°C. Między szóstym a szesnastym dniem życia ulega ona stałemu podwyższeniu i osiąga wartość nieco ponad 37°C. W kolejnych grupach wiekowych, do dwudziestego miesiąca życia, utrzymuje się na stałym poziomie, który średnio wynosi 37.7±0.6°C (Tabela 1). Zmianom temperatury ciała towarzyszy wraźny wzrost tempa metabolizmu. Wzrost ten najwyraźniej jest zaznaczony w warunkach fizjologicznego chłodu (Tabela 2). I tak przy temperaturze otoczenia równej 18°C norniki w grupie wiekowej 13—16 dni zużywają ponad czterokrotnie więcej tlenu niż w wieku 2—5 dni. Natomiast przy temperaturze 25°C i przy 32°C podwyższenie tempa metabolizmu jest znacznie mniejsze (Tabela 2). Oznacza to, że nierównomiernemu wzrostowi temperatury ciała w okresie postnatalnym towarzyszy duży, choć także nierównomierny, wzrost tempa metabolizmu.