ANALYSIS OF THE PATTERN OF ENERGY EXPENDITURE OF RATS IN DIFFERENT AGE PERIODS

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The few investigations which have been made of the character of the changes in the basal metabolism of rats at different age periods were conducted at an environmental temperature of 28-29° [8, 11], which differs substantially from the natural conditions of existence, not only of adult rats, but also of animals of the same species in younger age groups. The object of the present study was to examine the pattern of the oxygen consumption of rats in different age periods in a gas-exchange chamber at a temperature corresponding to the normal environmental temperature at which they live.

METHODS

The level of oxygen consumption, from which the intensity of energy expenditure at the different age periods could be judged, was determined by Grad's [16] method, slightly modified. Soda lime was used to absorb CO_2. This method is convenient, for by changing the size of the chamber depending on the age and size of the animals, their oxygen consumption can be measured accurately. The respiration chamber was immersed in a bath, maintained at the required temperature. Measurement of the oxygen consumption began 15-20 min after the animals had been placed in the chamber, and was then repeated at intervals of 5 min for a period of 15 min. Usually the oxygen consumption after each 5-min interval was identical or nearly so. The few experiments in which the values of the oxygen consumption after these intervals did not agree were not taken into consideration. The level of the oxygen consumption (in ml/min) was calculated per unit weight, and also per unit area of body surface. The surface area was calculated from Meeh's formula:

$$S = kW^{2/3},$$

TABLE 1. Limits of Variation of Body Temperature of Rats in Postnatal Ontogenesis when Kept in a Nest at 23°

Age (in days)	Rectal temperature (in degrees)
1-3	32.0-33.6
4-5	33.9-34.7
6-7	34.6-34.9
8-10	34.9-35.4
11-17	35.0-36.3
18-26	36.2-36.9
27-30	36.6-37.0
60 and more	37.2-37.6

TABLE 2. Limits of Variation of Oxygen Consumption in Rats in Postnatal Ontogenesis in a Respiration Chamber at a Temperature of 28°

Age (in days)	O_2 consumption (ml/kg/min)	O_2 consumption (ml/m^2/min)	Number of animals
1-3	25.8-26.8	51.6-57.8	11
8-9	25.1-32.5	62.6-85.4	13
11-12	46.4	132.7-133.5	4
13-14	72.1-72.8	211.4-218.3	5
15-16	62.0-65.0	194.3-202.4	3
17-18	77.6-85.8	242.3-279.5	4
19-25	57.6-65.2	207.4-230.7	5
30	42.4-46.0	261.0-179.7	3
60	31.0	180.9-185.4	2
Adult	28.3-28.8	190.6-206.3	6

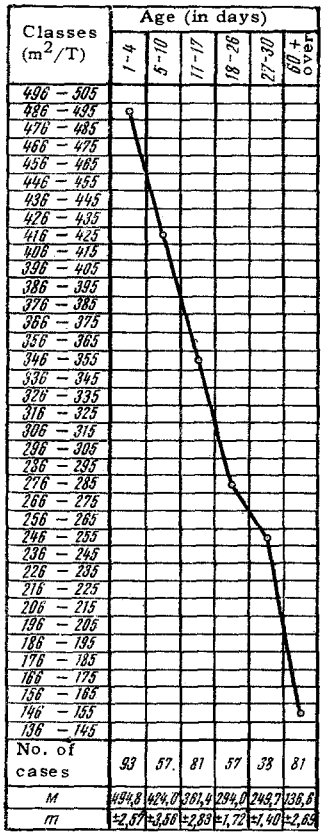

Fig. 1. Change in relative body surface area of rats in postnatal ontogenesis.

where S is the body surface area, W the body weight, and k a coefficient with the value of 9.1 for rats. The experiments were carried out on 407 rats of different ages, starting from the first day of life. The body temperature was measured in the rectum by means of an electrothermometer mounted in a thin, blunt needle.

RESULTS

The purpose of the preliminary investigations was to study the specific features distinguishing the physiology of rats in early age periods, which must be considered when the pattern of their gas exchange is analyzed. Young rats, kept apart from their mother (age 1.0-1.5 months or more), were taken for investigation 10-12 h, and adult rats 14-16 h, after taking their last meal. This time corresponded to the onset of the resting state after the final disappearance of the influence of the specific dynamic action of the food; the value of the oxygen consumption then corresponded to the degree of the basal metabolism.

At an early age, and especially in the first days of life, the very short waking period (every 2.5-3 h) coincided with the taking of food. If the rats in the first days of life were deprived of their usual feed of mother's milk, then after 1 h, and especially after 2 h, their body temperature fell by 2-4°, and gradually approximated the external environmental temperature. This was observed even when they were kept in the nest. In young rats deprived of their usual feed of mother's milk, a lower level of oxygen consumption and much lower resistance to a lowering of the external environmental temperature were observed than in rats which had been fed. It was found that an essential condition for the investigations in the respiration chamber on young rats in the first days of life is that they must be kept in a nest. In these circumstances the natural body temperature of the young rats in the first days of life was 32°.

The open top of the nest was in contact with the atmosphere, the temperature of which was 23° when the rats were kept in cages.

To investigate the oxygen consumption by young rats in the first days of life, they were placed in a specially constructed cotton-wool nest, as near natural as possible. The temperature of the respiration chamber was maintained at the level of 23°. Four young rats of the same weight were selected from a litter and placed in the nest which was, itself, placed in the respiration chamber.

a

Classes (O_2 ml/kg/min)	Age (in days)					
	1-4	5-10	11-17	18-26	27-30	60 + over
103 – 105						
100 – 102						
97 – 99						
94 – 96						
91 – 93						
88 – 90						
85 – 87						
82 – 84						
79 – 81						
76 – 78						
73 – 75						
70 – 72						
67 – 69						
64 – 66						
61 – 63						
58 – 60						
55 – 57						
52 – 54						
49 – 51						
46 – 48						
43 – 45						
40 – 42						
37 – 39						
34 – 36						
31 – 33						
No. of cases	59	38	57	52	28	35
M	50,5	62,7	104,6	66,4	54,5	35,0
m	±0,46	±1,08	±1,32	±1,01	±0,59	±0,31

b

Classes (O_2 ml/m^2/min)	Age (in days					
	1-4	5-10	11-17	18-26	27-30	60 + over
323 – 332						
313 – 322						
303 – 312						
293 – 302						
283 – 292						
273 – 282						
263 – 272						
253 – 262						
243 – 252						
233 – 242						
223 – 232						
213 – 222						
203 – 212						
193 – 202						
183 – 192						
173 – 182						
163 – 172						
153 – 162						
143 – 152						
133 – 142						
123 – 132						
113 – 122						
103 – 112						
93 – 102						
83 – 92						
No. of cases	59	38	57	52	28	35
M	93,8	133,6	323,6	233,6	228,0	255,7
m	±1,31	±4,29	±6,24	±2,96	±2,13	±4,74

Fig. 2. Change in oxygen consumption in rats in postnatal ontogenesis; a) oxygen consumption calculated per unit of body weight; b) oxygen consumption calculated per unit of body surface.

The natural body temperature of the rats at different age periods, starting with the first day of life, is shown in Table 1. In young rats in the first day of life the body temperature fell by 0.7-1.0° during their stay in the respiration chamber; when three young rats were placed in the nest their body temperature fell by 1.5-2.0°. The body temperature of young rats aged 4-5 days fell by 0.6-0.2° during their stay in the respiration chamber. After the 6th-7th day the rats were placed in the respiration chamber (in the nest or not) one at a time. The main series of investigations, as mentioned above, was carried out when the temperature in the respiration chamber was 23°, and a smaller number of observations was made at 28° (Table 2). In the latter case the young rats in the first day of life were placed uncovered on a bed of cotton wool.

The mean oxygen consumption of the young rats in the first 3 days of life, when kept in the respiration chamber at a temperature of 28°, was 26.3 ml/kg, and at 23° it was 50.5 ml/kg/min. Hence, it follows that when conditions are observed which satisfy the specific physiology of the neonatal organism, from the first few hours of life the young rats exhibited a well marked function of chemical thermoregulation. The changes in the oxygen consumption at different environmental temperatures were not analyzed in greater detail.

The curve in Fig. 1 shows the change in the relative size of the body surface in rats in different age groups. According to the "surface energy rule," the change in the oxygen consumption calculated per unit of body weight must accurately reflect the change in the relative size of the body surface, and the change in the oxygen consumption calculated per unit of body surface must be represented by a horizontal line throughout the period of postnatal ontogenesis. Curves are given in Figs. 2a and 2b showing the actual change in the level of oxygen consumption calculated per unit of weight and per unit of body surface.

Our investigations showed that until the 16th-17th day of life a gradual increase in the oxygen consumption per unit of body weight of the animal was observed. Not until the 17th-18th day, or in fact, after the rats had become able to stand, did a progressive decrease in the oxygen consumption take place, reaching its minimal values in the adult period (Fig. 2a).

Contrary to the "surface energy rule," the oxygen consumption per unit body weight is known to rise at first, and it does not begin to fall until the age of 1 month [13, 14].

Like the oxygen consumption per unit of body weight, the oxygen consumption per unit of body surface also rises initially, reaching its maximum on the 16th-17th day of life (Fig. 2b). When calculated per unit of body weight, the oxygen consumption rose by slightly more than 100%, and when calculated per unit of body surface, it rose by 250%. Starting on the 17th-18th day, the oxygen consumption per unit of body surface fell, reaching a minimum at the age of 1 month, after which it began to rise gradually again towards the adult period.

It is concluded from these results that the oxygen consumption, which reflects the intensity of energy expenditure, when calculated both per unit of body weight and per unit of surface area, does not conform to the "surface energy rule" during the period of postnatal ontogenesis.

SUMMARY

A study was carried out of the characteristics of oxygen consumption at different age periods in rats kept in a respiratory chamber at a temperature corresponding to that in their natural habitat. The experiments were carried out on 407 animals. In albino rats the oxygen consumption increases after birth both per unit of weight and per unit of body surface, reaching the maximum at the time of assuming the standing posture (11th-17th day after birth) —104.6 ml/kg weight and 323.6 ml/m^2 body surface per minute. During subsequent postnatal development oxygen consumption both per unit of weight and per unit of body surface gradually decreases. At the same time, a progressive decrease in oxygen consumption occurs per unit of body weight up to the adult period, reaching 35.0 ml/kg per min. The oxygen consumption per unit of body surface falls only until one month of age, after which it increases again. It is concluded that change in oxygen consumption reflecting the energy expenditure rate in the postnatal ontogenetic process does not conform to the "surface energy rule."

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