ROLE OF THE WATER BALANCE FOR ANIMAL GROWTH DURING HYPERKINESIA

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UDC 612.744.15.014.461.3-06:612.76

KEY WORDS: hyperkinesia, animal growth, skeletal muscle

All processes important for life take place in aqueous solutions of inorganic and organic matter [1]. Muscles, it has been noted, are not only organs of movement, but they are also among the most important depots of water and electrolytes. Increased muscular activity is reflected in the work of various systems of the body, which maintain water and electrolyte metabolism [5, 6]. It has been shown for members of different classes of vertebrates that, if the diet is deficient in water the working capacity of their skeletal musculature is considerably reduced. Introduction of water into the body restores the weakened functions of the muscles [1, 3, 4]. The water balance is particularly important in young animals [7].

It was interesting to investigate the dynamics of growth of young animals in relation to their motor activity and water balance. To obtain some idea of the role of physical exercise and the water content of the diet on the muscular system, it was decided to study a large and intensively working muscle of the hind limb, namely the gastrocnemius. The investigation served two aims: 1) to study growth of young animals and their skeletal muscles under conditions of hyperkinesia; 2) to study the role of the water balance in the time course of the increase in body weight of young animals under conditions of hyperkinesia.

EXPERIMENTAL METHOD

In the experiments of series I, 37 noninbred male rats weighing 115-125 g, divided into three groups, were used: animals of group 1 were kept in cages measuring 23 × 35 × 31 cm, rats of group 2 in cages measuring 50 × 14 × 24 cm. In both experimental groups the feeding bowls were suspended from the ceiling of the cage. Animals of group 3 (the control) were kept in ordinary animal house cages measuring 16 × 35 × 31 cm, and they were fed through the lower part of the anterior wall of the cage. All animals in the experiments of series I received food and water ad lib. The experiments continued for two months. The criterion of growth of the rats was their body weight. The animals were weighed weekly in the morning before being fed. The results were analyzed by Student's test, after which the increase in their body weight was presented graphically. After two months the rats were killed and the gastrocnemius muscles were dissected in both hind limbs and weighed. The material was fixed in Zenker's fluid. Sections were stained with iron-hematoxylin by Reguad's method, with and without counterstaining by Mallory's method.

In the experiments of series II, 36 male albino rats weighing 100-110 g, divided into four groups, were used. The volume of water consumed was measured individually for each animal by measuring the volume of fluid drunk per day. The measurements were made during the first week before the experiment began. Rats of group 1 were kept in cages measuring 23 × 35 × 31 cm. The feeding bowls were suspended from the ceiling of the cage, and drinking bowls were placed below. The animals were given water ad lib. Rats of group 2 were kept in the same cells, but were allowed only half as much water. Rats of group 3 were kept in ordinary animal house cages measuring 16 × 35 × 31 cm. The feeding and drinking bowls were placed in the bottomof the cage, and water was provided ad lib. Animals of group 4 were kept in the same cages as those of group 3, but received only half as much water. The experiment continued for 2.5 months. The animals were given their ordinary diet (the daily ration per rat in micrograms was: bread 10, cottage cheese 5, vegetable oil 1, fish or meat 15, groats 10, polyvitamins 0.05, vegetables 15, grain 40, salt 0.4, hay 10, starch 0.4, fish oil 0.1, chalk 0.1).

Laboratory of Evolutionary Histology, A. N. Severtsov Institute of Evolutionary Morphology and Ecology of Animals, Academy of Sciences of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR A. P. Avtsyn.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. No. 12, pp. 734-736, December, 1985. Original article submitted November 16, 1984.

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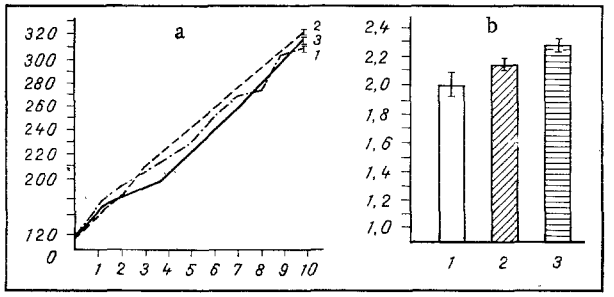

Fig. 1.

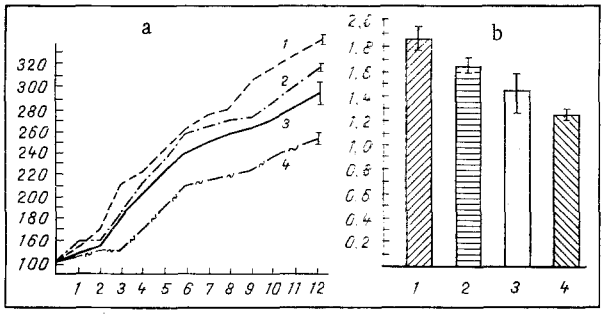

Fig. 2.

Fig. 1. Body weight (a) and weight of gastrocnemius muscles (b) of experimental animals. Abscissa: a) time of experiment (in weeks); ordinate (a, b) weight (in g). 1) rats kept in ordinary cages; 2, 3) rats kept in cages 23 and 50 cm high respectively.

Fig. 2. Body weight (a) and weight of gastrocnemius muscles (a) of rats kept under different conditions of motor activity and water balance. 1) Conditions of hyperkinesia without restriction of water; 2) conditions of hyperkinesia + half the portion of water; 3) ordinary cages with water ad lib; 4) ordinary cages and half the portion of water. Remainder of legend as to Fig. 1.

Once a week the rats were weighed in the morning before feeding. At the end of the experiment the rats were killed and the gastrocnemius muscles of both hind limbs were dissected and weighed. The numerical results were analyzed as in the experiments of series I.

EXPERIMENTAL RESULTS

In series I in both experimental groups the rats had to make greater efforts in order to obtain food. The animals of group 1, kept in cages 23 cm high, had first to climb the cage walls, then to stretch for the food, standing on their hind limbs. The animals of group 2 (height of cage 50 cm) had to spend their whole time climbing the cage wall for food, i.e., they spent more time in movement. The body weight of the rats of group 1 gradually increased, reaching 324±5.21 g at the end of the experiment. The body weight of the animals of group 2 rose to 321±8.00 g. In rats of control group 3, the body weight at the end of the experiment was 309±5.41 g. Differences in the gain in body weight of rats of all three groups of the experiments of series I are shown by the graph in Fig. 1a as a function of the amount of motor activity. The difference in body weight of the animals of groups 1 and 3 was 15 g, which lay on the borderline of significance ($P \leq 0.1$). The difference in body weight of the rats of groups 2 and 3 was 12 g, which was not significant. Differences in weight of the gastrocnemius muscles of animals of all three groups in the experiments of series I are shown in Fig. 1b. The weight of the gastrocnemius muscles two months after the beginning of the experiments was 2.132±0.072 g in rats of group 1, 2.258±0.080 g in rats of group 2, and 1.997±0.100 g in rats of the control group. These results indicate that with an increase in motor activity of the young animals their general growth showed a tendancy to take place more rapidly, as shown by the difference in body weight between the experimental and control rats. Weighing the gastrocnemius muscles, which in the experimental animals carried a greater physical load than in the controls, showed that they weighed the most in rats of group 2, which had to move more in order to obtain food. The difference in weight of the gastrocnemius muscles in the animals of groups 2 and 3 was 0.261 g. However, the difference was not significant. It will be noted that although the body weight of rats kept in the tallest cages was lower than in rats kept in cages of average height, the weight of their gastrocnemius muscles was greater, evidence that movement promotes an increase in muscle weight.

In the experiments of series II on animals of group 1, kept in cages 23 cm high, i.e., under conditions of hyperkinesia with no restriction of water, the body weight increased during the period of observation to 333±6 g. In the rats of group 2, kept in the same cages but on a restricted water intake, the body weight rose to 308±5 g. In animals of group 3 (control), kept in ordinary animal house cages and receiving water ad lib., the body weight was 284±19 g. In the rats of group 4, kept in the same cages as those of group 3, but on a restricted water intake, the body weight was the lowest of all, namely 242±8 g (Fig. 2a). Differences in the gain in body weight, depending on motor activity and water intake, were significant between

groups 1 and 2 ($P < 0.05$), and between groups 3 and 4 they were on the borderline of significance. Differences in weight of the gastrocnemius muscles in animals of all four groups in the experiments of series II are illustrated by the data shown in Fig. 2b. The difference between groups 1 and 2 and also that between groups 3 and 4 were not significant. As the results show, restriction of water in the diet had a particularly marked effect on the body weight of rats under conditions of hyperkinesia: at the end of the experiment the body weight of the animals kept in the lowest cages, with suspended feeding bowls, and receiving water ad lib., was significantly greater than the body weight of rats receiving a restricted water intake. If the animals were kept in ordinary cages, restriction of water in the diet had a less marked effect on their growth: the difference in body weight of the rats was on the borderline of significance, which confirms data obtained previously [2]. Analysis of the results of weighing the gastrocnemius muscles showed that restriction of the water intake, in both ordinary and taller cages, caused a decrease in weight of the gastrocnemius muscle compared with their weight in rats receiving water ad lib. However, this difference was not statistically significant, a fact which also confirms previous data [2].

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