Effects of Exercise on Growth, Resting Metabolism, and Body Composition of Fischer Rats[1] (34645)

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While voluntary exercise in rats was studied, it was noted that those allowed to run in revolving cages gained weight more rapidly than those confined in the usual cages where very little exercise was possible. Since the controls were not litter mates and the experiments were not done over the same period of time, it was decided that these observations should be repeated, using litter mates and adding other measurements to try to account for the differences in weight of the two groups.

Method. Twelve pairs of female Fischer litter mates about 50 days of age were selected for this study and were placed in cages with revolving wheels (Acme Metal Products Company, Chicago, Ill.). One of each pair was confined to the small chamber where food and water were provided but very little activity was possible The other could enter a revolving wheel with a circumference of 1.1 m and run at will. The food intake, and revolutions of the wheel were determined weekly and oxygen consumption at rest was measured about once a month (13, 14). When the rats were about 150 days of age, they were killed with an overdose of ether and their weight and body length were determined. The following parts were dissected out, weighed and then put back with the rest of the carcass: liver, heart, the gastrocnemius-soleus, the quadriceps femoris, the adrenals, and the kidneys. The entire carcass was then ground in a Waring Blendor as previously described (9). Aliquot samples were removed for water and fat determinations.

Results and Discussion. Body weight, food intake and activity. The body weight in 10 of the 12 control rats increased more slowly than did that of the rats allowed to exercise. At the end of 10 weeks the control rats had a mean weight of 148.9 ± 5.0 g whereas those that exercised weighed 174.7 ± 4.1 g (see Table I). The groups had at the start weighed 97.1 ± 5.0 and 98.7 ± 5.3 g, respectively, [see (4) and (16)]. During the first week the food intake was essentially the same, 71.0 ± 2.1 g for controls and 74.8 ± 3.0 for the active rats. At the end of 10 weeks these groups were eating 68.6 ± 3.0 and 104.7 ± 4.0 g, respectively. The rats allowed to exercise started out by turning the wheel an average of 700 rev/week and 10 weeks later, 38,900 rev/week or about 5 km/night.

Oxygen consumption and activity. Basal oxygen consumption decreases during the period of rapid growth of the rats (13). The closely confined rats at 87 days of age had an oxygen consumption of 768 ± 28 ml/hr/kg$^{.75}$ and at 122 days was 704 ± 21 ml. In the active rats the basal values were 882 ± 19 and 776 ± 15 for the similar ages. Ten out of 12 of the active litter mates had a higher basal oxygen consumption than their inactive controls. The difference in the results at each age is significant.

Activity and lipid and water content of growing rats. The whole body lipid of the active rats at 149 ± 10 days of age was 4.03 ± 1.25% of the total body weight and of the inactive rats 6.71 ± 2.11%. The latter values are similar to previous results (6.27 ± 1.07%) obtained on inactive female rats about 200 days of age (9). The difference in lipid between the active and inactive groups is not significant. When the experiment began with this group of rats, they were 56 days old. A similar group at this age had a lipid content of 3.22 ± 1.63 g/100 g of body weight.

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TABLE I. Effects of Exercise on Metabolism of Growing Rats.

	Group A[a]	Group B[b]	Group C[c]	p for Groups B vs. C
Food intake per week				
1st week/rat	—	71.0 ± 2.1[d]	74.8 ± 3.7	NS[e]
10th week/rat	—	68.6 ± 3.0	104.7 ± 4.0	<.001
10th week/kg of rat	—	448 ± 20	581 ± 22	<.001
Whole body lipid/100 g of rat	2.22 ± 1.63	6.71 ± 2.11	4.03 ± 1.25	NS
Whole body water/100 g fat-free tissue	75.44 ± 3.92	72.65 ± 1.95	75.46 ± 4.40	NS
Oxygen consumption (ml/hr/kg$^{.75}$)				
At 100 days of age	—	768 ± 28	882 ± 19	<.01
At 135 days of age	—	704 ± 21	776 ± 15	<.01

[a] Control group
[b] Minimal exercise group.
[c] Maximal exercise group.
[d] Standard error of mean.
[e] Not significant.

The whole body water content per 100 g of fat-free tissue was for the active group 75.5 ± 4.4 g and for the inactive group 72.7 ± 1.9 g. The 56 day old rats had 75.4 ± 3.9 g. The differences in water content are not significant.

Activity and development of parts of the body during growth. The effects of exercise on the growth of various parts of the body are shown in Table II. The body length increased significantly more in the active rat than in the inactive one. All of the organs which were weighed were also larger in the active rats. However if the weight of these organs is calculated as a percentage of the whole body, then the differences disappear

TABLE II. Effects of Exercise on Growth of Rats.

	Group A[a]	Group B[b]	Group C[c]	p for Groups B vs. C
Age	56 ± 0.5	148 ± 3.3	149 ± 3.3	NS
Body wt	84.6 ± 2.6	148 ± 5.0	174.7 ± 4.1	<.001
Nose to anus length (cm)	15.6 ± 0.2	18.5 ± 0.2	20.0 ± 0.2	<.001
Adrenals (g)	0.017 ± 0.001	0.026 ± 0.001	0.037 ± 0.002	<.001
Adrenals (g/kg)	0.204 ± .011	0.178 ± 0.005	0.212 ± 0.009	<.01
Kidney (g)	0.452 ± .017	0.660 ± 0.023	0.766 ± 0.022	<.01
Kidney (g/kg)	5.350 ± 0.121	4.432 ± 0.070	4.396 ± 0.137	NS
Liver (g)	4.750 ± 0.314	6.135 ± 0.135	7.297 ± 0.241	<.01
Liver (g/kg)	55.789 ± 2.507	41.172 ± 1.617	41.813 ± 1.160	NS
Heart (g)	0.367 ± 0.012	0.492 ± 0.018	0.614 ± 0.017	<.001
Heart (g/kg)	4.348 ± 0.104	3.308 ± 0.067	3.520 ± 0.061	NS
Gastrocnemius-soleus (g)	0.516 ± 0.019	0.951 ± 0.030	1.511 ± 0.029	<.001
Gastrocnemius-soleus (g/kg)	6.084 ± 0.071	6.397 ± 0.096	6.589 ± 0.076	NS
Quadriceps (g)	0.696 ± .025	1.264 ± 0.053	1.611 ± 0.038	<.001
Quadriceps (g/kg)	8.218 ± 0.087	8.483 ± 0.175	9.227 ± 0.090	<.001

[a] Control group
[b] Minimal exercise group.
[c] Maximal exercise group.

except in the adrenals and in the quadriceps-femoris group of muscles. These grew at a greater rate than the body as a whole but the gastrocnemius-soleus group grew at a rate proportional to body weight.

Earlier, Donaldson and Meeser (4) obtained evidence indicating that exercise did not modify body size or length of bones but that most organs increased in weight more than those of controls. Von Béznak and Sarkady (16) found forced exercise resulted in less gain in weight during growth in both male and female rats (237 g for exercising males and 259 g for controls and for females 214 and 210 g) and no marked effect on the weight of organs except for the adrenal glands which were 20-30% heavier in the exercising animals.

Food intake, growth, and activity. The rate of growth of animals depends upon a number of factors—the environment, food supply, inheritance, and endocrines—all of which may be interrelated. Inheritance, ambient environment, and the type of food supplied were the same in both groups of animals. The amount of food ingested by the control rats was less than that eaten by the exercising animals and one may calculate roughly in these, the gross efficiency for growth. Subtracting the basal energy requirement and assuming 2 cal of stored energy for each gram of weight added, our values for the control rats show 4% efficiency. The similar value determined by Mitchell and Carman (10), was 6–14% and by Cohn and Joseph (3), 11.9%.

For the rats allowed to exercise, there is no good way to separate the energy required for growth from that for exercise. If one calculates the difference in food intake of the litter mates, ignoring the fact that the exercising rats grow more rapidly than their controls, one can estimate the food required for turning the wheels 1000 rev. This is found to average 0.37 g of food/100 g of rat. This is less than the 0.5 g/1000 rev found in previous studies based on different levels of activity in the Fischer rat (13). The previous study was on mature rats who gained very little weight. It should be remembered that the active rats probably store less fat but even correcting for this changes the value very little— to 0.39.

Basal oxygen consumption and exercise. The basal oxygen consumption of normally caged and therefore inactive female rats 250 days of age was previously found to be 752 $\pm$ 10 ml/hour/kg$^{.75}$ and for rats living in revolving cages and therefore quite active was 799 $\pm$ 11 (13). No satisfactory explanation is at hand to account for the difference in metabolic rates between the two groups. With the exception of the quadriceps-femoris group of muscles and the adrenal glands, the body parts are proportional to body weight. The more rapid growth of the quadriceps of itself should result in a decrease in the whole body metabolism since resting skeletal muscles are believed to use energy at a very slow rate (1) and if the muscle mass increases more than the rest of the body, this in itself would be expected to lower the mean metabolic rate.

As to the adrenal glands, the release of epinephrine from the medulla could elevate metabolism but it is usually believed that these glands are active only when the animal is excited. There is no evidence that the cortex elevates metabolism.

Hormones and growth. It is well known that growth is influenced by steroids, thyroid, and somatotropic hormones and to a lesser extent by many other hormones (5). There appears to be no evidence however, that exercise is accompanied by increased thyroid activity nor is the growth pattern in our rats similar to that produced by giving thyroid hormone (6). On the other hand, Roth *et al.* (15) found that the secretion of growth hormone is stimulated by exercise. Furthermore, when growth hormone is given, some muscles grow more rapidly than others and the body stores less fat (7, 8, 12)—changes similar to those we observed. The increase in adrenal weight resulting from voluntary exercise in our rats is similar to that found by Von Besnák *et al.* (16) in rats forced to exercise.

Composition of rat carcass. It is well known that athletes have less fat than others of the same weight (2, 17, Pitts (11) has shown that male guinea pigs forced to exercise from the time of weaning were lighter than controls and had less extractable fat. Our rats exercising voluntarily were heavier than nonexercising ones and their body fat was perhaps slightly less.

Summary. Young Fischer rats allowed to exercise grow at a faster rate than litter mates confined to small quarters. The bodies of both groups of rats contain the same amount of water. The growth of the parts studied is proportional to body size except for the adrenal glands and the quadriceps-femoris group of muscles. These grow at a greater rate than the body as a whole. The basal metabolism in the rats allowed to exercise is higher than that of the controls.

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