Voluntary Exercise during Pregnancy and Lactation and Its Effect on Lactational Performance in Mice

Kuniko KARASAWA, Junichi SUWA, and Shuichi KIMURA

Laboratory of Nutrition, Faculty of Agriculture, Tohoku University, Sendai, Miyagi 980, Japan
(Received October 6, 1980)

Summary The amount of voluntary exercise during pregnancy and lactation and its effect on the lactational performance in mice were investigated. Female mice were housed in exercise cages with treadwheels during periods of growth, pregnancy and lactation and the amounts of exercise were measured. It was observed that growing female mice exercised voluntarily at a level of approximately 5,000 rotations (diameter of treadwheel; 13.5 cm) per day during the 4-week growth period. After conception, the amount of exercise gradually decreased and in late pregnancy running activity decreased markedly. Throughout the lactational period dams exercised lightly. As indices of lactational performance, the body weights of pups nursed in litters of 8, milk yield and cellular development of abdominal-inguinal mammary glands were examined. There were no significant differences in the final body weights of pups, milk yield per day or development of mammary glands between exercise and non-exercise groups.

Key Words pregnancy, lactation, voluntary exercise, mammary glands, carcass composition, milk yield

Pregnant women have a low level of physical activity. Therefore, it is necessary to determine the advisability of taking exercise during pregnancy and lactation. Parizkova (1, 2) reported that exercise during pregnancy affects the metabolic functions of pups after birth.

In 1923, Wang (3) reported on voluntary running activity in female rats during pregnancy and lactational periods. He showed that pregnant and lactating rats exercised little, but did not study the effect of voluntary exercise on lactation and the outcome of pregnancy. On the other hand, the studies of Parizkova (1, 2) included forced exercise in pregnant rats and its effect on their offspring. However, the effect of exercise on the lactational performance was not investigated.

In this report we have made studies to determine the amount of voluntary

1 唐沢久仁子, 話訪純一, 木村修一
exercise done during pregnancy and lactation by animals kept in cages with treadwheels and to determine the effect of exercise on the functions of pregnant and lactating mice.

**METHODS**

Several methods have been employed (4) for the estimation of the lactational performance or mammary gland function of small mammals. Among them, as an index of lactational performance, we used pup body weight, suckled milk quantity as determined in a given time of nursing and deoxyribonucleic acid content of the mammary glands on day 14 of lactation.

*Animals and their treatments.* Weanling, female JCL: ICR mice (Japan Clea Inc., Tokyo) were used in this experiment. The composition of experimental diet is shown in Table 1. Throughout the experiment all mice were fed on this diet and were given water *ad libitum*. All mice were maintained in a temperature controlled room (25 ± 1°C) with 12 hr light (8:00 to 20:00) and 12 hr darkness (20:00 to 8:00). They were housed individually in wire net cages for one week. After this period, they were divided into exercise and non-exercise groups. The exercise mice were housed individually in stainless steel wire-net cages with a plastic revolving

| Table 1. Composition of diet. |
|-------------------------------|
| %                            |
| Corn starch                   | 69.7 |
| Milk casein                   | 20.0 |
| Soybean oil                   | 5.0  |
| Salt mixture *a*              | 4.0  |
| Choline chloride              | 0.2  |
| Water soluble vitamin mixture *b* | 1.0  |
| Fat soluble vitamin mixture *c* | 0.1  |

*a* Harper's salt mixture. 
*b* Harper's water-soluble vitamin mixture. 
*c* Fat soluble vitamin mixture: Vitamin A, 1,500 IU/100 g diet; vitamin D, 100 IU/100 g diet; vitamin E, 10 mg/100 g diet.

![Fig. 1. Apparatus for detecting treadwheel rotation. a, revolving treadmill; b, magnet; c, sensor (lead switch); d, converter; e, electromagnetic counter.](image-url)
treadwheel (diameter: 13.5 cm, width: 6 cm) fixed with a small magnet. The revolving treadwheel allowed the animals to exercise voluntarily. Rotation of the treadwheel was detected by a magnetic sensor (lead switch) and the number of rotations was recorded by electromagnetic counter (Fig. 1). The non-exercise mice were housed individually in wire net narrow cages to restrict their voluntary movement.

After 4 weeks, at 8 weeks of age, the mice were mated with males of the same strain. Mating was confirmed daily by the presence of sperm in the vaginal smear. The day when sperm was found was considered as day zero of gestation. After conception, the exercise group continued voluntary exercise. Since both groups were bred in wire net cages, sheets of paper for nesting were supplied for each cage.

Checking for birth was done at 8:00 a.m. every morning, and the day when a litter was found was designated as day 1 of lactation. The litter size was adjusted to 8 pups on day 2 of lactation. The pups were weighed every other day from day 2 to day 14 of lactation. Suckled milk quantity was estimated on the 13th to 14th day of lactation. Young were separated from their dams and fasted for 5 hr, followed by suckling for 1 hr. The difference in the weight of the 8 pups before and after 1 hr suckling was considered as milk yield for 5 hr. By repeating this method four times in 24 hr (5), the cumulative figure was considered as the total milk yield per day.

Removal of organs and tissues. After estimation of milk yield, dams were killed by cutting the carotid artery and dissected. Both abdominal and inguinal mammary glands were quickly removed and placed in weighed containers with ice-cold buffered saline (0.15 M sodium chloride, 0.1 M sodium acetate), and then weighed (6). After this treatment glands were stored at -20°C until analyzed. The heart, liver, kidneys, spleen and abdominal depot fat tissue were also removed and weighed.

Analysis of tissue and carcass. Mammary glands were lyophilized and defatted by ether. The dried, defatted tissue (DDFT) was weighed and finely ground with a vibrating mill. Then DNA was extracted in accordance with the method of Schneider (7) and determined by the diphenylamine method (8) using calf thymus DNA as a standard.

Carcasses of dams were freeze-dried. The weight loss in drying was counted as water content. The crude fat content of carcass was estimated with the Soxhlet apparatus. Then, dried, defatted carcasses were finely ground with a vibrating mill and the nitrogen content was determined by the semimicro-Kjeldahl method. The protein content was calculated by multiplying the nitrogen content by 6.25. The ash content was determined by placing the carcass powder in a muffle furnace overnight at 600°C.

Student's t test was used for the statistical evaluation of the data.

RESULTS AND DISCUSSION

Running activity of female mice from the 4th to 7th week of age is shown in Fig. 2. Running activity in this period was approximately 5,000 rotations/day.
Figure 3 shows the activities in the periods of pregnancy and lactation. Exercise decreased gradually from around the second week of gestation and reached about 500 rotations at term. After parturition, running activity did not increase and was maintained at a low level. The activity of the control virgin mice is also shown in Fig. 3. Slight decreases in activity were seen with age. Table 2 shows the number of pups on day 2 of lactation, the initial (on day 2) and final (on day 14) body weight of pups and milk yield from days 13 to 14 of lactation. In the exercise group the final body weight of the pups and milk yield were slightly greater than those in the non-
exercise group, but the differences were not significant. Wet weight and composition of abdominal-inguinal mammary glands are shown in Table 3. There were no significant differences between the two groups. Table 4 shows tissue weight and carcass composition of dams and virgin mice. In virgin mice there were significant differences in carcass fat and weight of abdominal depot fat, due probably to exercise. In dams, however, with the exception of spleen weight, there were no significant differences between the exercise and non-exercise groups. The content of carcass fat of dams was about half that of virgin mice regardless of exercise. Two reasons for these results are offered: one is that both groups had very low physical activity during lactation. The other is that lactating mothers consumed large amounts of body fat for milk production.

Parizkova (1) reported that the number of muscle fibers and capillaries per mm² of the heart was significantly higher in the male offspring of exercised mothers.
than those of non-exercised dams. The exercise in that experiment was a daily work-load of 1 hour's running on a tread-mill at a speed of 14 to 16 m/min throughout pregnancy. Moreover, she (2) reported that a daily work-load during pregnancy resulted in significant changes of lipid metabolism in the liver and small intestine of the offspring. On the other hand, Lamb et al. (9) investigated whether forced exercise in Holstein heifers is favorable for milk production or not. They found that exercise-load during pregnancy improved the ease of calving, hastened the postpartum release of the placenta and resulted in the production of more milk. The exercise procedure used by Parizkova and Lamb et al. was forced exercise. On the other hand, Wang (3) observed the amount of spontaneous exercise during periods of pregnancy and lactation, but did not study its effect on pregnancy and lactation. In the present experiment, we studied the amount of voluntary exercise during pregnancy and lactation and the effect of voluntary exercise on lactational performance in mice. With advancing gestation, the amount of voluntary exercise gradually decreased, but a sharp decrease immediately after conception was not found, as Wang (3) had reported. The decrease in physical activity seems to be due to the remarkable increase in body weight. After parturition as well as during pregnancy, the amount of exercise did not increase, and this seems to be due to the prevention of free movement of mother by the suckling of her pups.

We examined whether exercising voluntarily has any effect on lactation. And it was observed that from late pregnancy running activity markedly decreased and throughout the period of lactation, dams exercised a little. Consequently, the

|                | Exercise (18)* | Non-exercise (16) | Exercise (8) | Non-exercise (8) |
|----------------|---------------|-------------------|--------------|------------------|
| Final body weight | 27.63 ± 1.99  | 28.35 ± 0.73      | 26.68 ± 1.81 | 27.49 ± 2.93     |
| Water %          | 71.86 ± 1.56  | 72.88 ± 1.91      | 64.65 ± 1.89 | 62.82 ± 2.76     |
| Fat %            | 5.82 ± 1.76   | 5.16 ± 1.36       | 12.14* ± 2.44 | 15.31 ± 2.97     |
| Protein %        | 16.55 ± 0.79  | 16.14 ± 0.34      | 16.82** ± 0.79 | 15.38 ± 0.43    |
| Ash %            | 3.32 ± 0.12   | 3.22 ± 0.08       | 3.86** ± 0.15 | 3.60 ± 0.10      |
| Heart g          | 0.15 ± 0.02   | 0.15 ± 0.02       | 0.14 ± 0.02  | 0.13 ± 0.02      |
| Liver g          | 1.41 ± 0.15   | 1.46 ± 0.20       | 1.00 ± 0.10  | 1.01 ± 0.13      |
| Kidneys g        | 0.38 ± 0.03   | 0.39 ± 0.03       | 0.38 ± 0.05  | 0.33 ± 0.05      |
| Spleen g         | 0.09* ± 0.02  | 0.11 ± 0.03       | 0.10 ± 0.04  | 0.10 ± 0.03      |
| Abdominal depot fat g | 0.84 ± 0.25  | 0.78 ± 0.24       | 1.50* ± 0.27 | 1.94 ± 0.39    |

Values mean ± SD. *Figures in parentheses represent numbers of mice. *p < 0.05, **p < 0.01 between exercise and non-exercise groups.

Table 4. Tissue weight and carcass analysis of dams and virgin mice.

J. Nutr. Sci. Vitaminol.
exercise group had a little voluntary exercise from just before delivery and during the period of lactation. Finally, there were no significant differences in weight gains of offspring, milk yield and development of mammary glands between the two groups. In this study, it was confirmed that exercise during pregnancy did not affect lactation. But it was impossible to observe the effect of exercise during nursing on lactation because there was low physical activity during the period of lactation. In future we must employ methods which make lactating mice exercise. And it is necessary to examine not only lactational function but also the physiological functions of pups whose mother exercised throughout pregnancy and lactation.

REFERENCES

1) Parizkova, J. (1975): Impact of daily work-load during pregnancy of the microstructure of the rat heart in male offspring. Eur. J. Appl. Physiol., 34, 323–326.

2) Parizkova, J. (1978): The impact of daily work-load during pregnancy on lipid metabolism in the liver of the offspring. Eur. J. Appl. Physiol., 39, 81–87.

3) Wang, G. H. (1923): The relation between 'spontaneous' activity and oestrous cycle in the white rat. Comp. Psychol. Monogr., 2, 1–27.

4) Nagasawa, H., Yanai, R., Kosugiya, M., and Fujimoto, M. (1969): Correlation between some characters as the indices of lactational performance of mouse. Jpn. J. Zootech. Sci., 40, 61–66.

5) Reddy, R. R., and Donker, J. D. (1965): Lactation studies. VI. Effect of different intervals between nursing and duration of suckling on rate of milk production in Sprague-Dawley rats in the first lactation. J. Dairy Sci., 48, 978–982.

6) Munford, R. E. (1963): Changes in the mammary glands of rats and mice during pregnancy, lactation and involution. 2. Levels of deoxyribonucleic acid, and alkaline and acid phosphatase. J. Endocrinol., 28, 17–34.

7) Schneider, W. C. (1945): Phosphorus compounds in animal tissues. I. Extraction and estimation of deoxypentose nucleic acid and of pentose nucleic acid. J. Biol. Chem., 161, 293–303.

8) Burton, K. (1956): The study of the conditions and mechanism of the diphenylamine reaction for the colorimetric estimation of DNA. Biochem. J., 62, 315–323.

9) Lamb, R. C., Barker, B. O., Anderdon, M. J., and Walters, J. L. (1979): Effect of forced exercise on two-year-old Holstein heifers. J. Dairy Sci., 62, 1791–1797.