Comparison of the Reproductive Performance of Rats at High Altitude (3,800 m) and at Sea Level*

Marita L. Nelson** and H. H. Srebnik**

INTRODUCTION

It is widely recognized that the fertility of most animals indigenous to sea level is reduced when they are moved to high altitudes (Altland, 1949; Mongé, 1960; Weihe, 1964). However, very little is known of the reproductive capabilities of rats derived from sea level stock but born at high altitude, i.e., first-generation natives. Previous reports on the reproductive performance of sea level native rats transported to high altitude as adults indicate that female animals may experience transitory anestrus (Chang and Fernandez-Cano, 1959; Weihe, 1964). However, when successfully mated, these animals give birth to first-generation offspring of normal size (Weihe, 1964; see also review by Dawes, 1968, p. 54). Ample evidence suggests that the postnatal growth of the first-generation rats at high altitude is significantly impaired (Chiodi and Sammartino, 1952; Krum, 1957; Moore and Price, 1948; Nelson, 1968; Timiras, 1964; Timiras and Woolley, 1966; Timiras, Krum and Peace, 1957). Reduced body weight and a reduction in the weight of most endocrine organs as well as cardiac hypertrophy and polycythemia have been reported in first- and second-generation rats at high altitude. Impaired fertility in these rats has been inferred; however, a search of the literature has failed to reveal any information concerning the reproductive performance of these animals. Consequently, a study of the reproductive capability of first-generation rats born at high altitude was conducted and comparisons were drawn with sea level control animals and sea level adult rats transported to high altitude. The estrous cycles of the three groups of animals were analyzed, and a comparison of their ability to maintain pregnancy was made including a study of the prenatal status of the fetuses from each group of animals.

MATERIALS AND METHODS

Three groups of female Long-Evans rats, approximately 120 days of age, were used in this study. The first group of 9 rats from the colony at Berkeley (elevation 76 m) served as sea level controls. The second group of 6 animals of Berkeley native stock was transported to Barcroft Laboratory of the White Mountain Research Station (3,800 m); the third group consisted of 11 first-generation native rats born at high altitude (3,800 m). At the onset of the experiment, the sea level controls and Berkeley native rats at 3,800 m weighed approximately 308 g, and the high altitude native rats weighed an average of 209 g. All animals were maintained under standard conditions of light, 14 hr of light and 10 hr of darkness, and temperature (20°C to 25°C), and were fed AD LIBITUM a standard laboratory

*) This research was supported in part by NIH Grant NS-08989 and NSF Grant GB 3171.

**) Department of Physiology-Anatomy, University of California, Berkeley, and the White Mountain Research Station, Bishop, California, USA. Present address of senior author: Department of Anatomy, Georgetown University Schools of Medicine and Dentistry, 3900 Reservoir Road, N.W., Washington, D.C., 20007, USA.

Received 20 April 1970.
diet. The diet contained 67.5% wheat, 15% casein, 7.5% skim milk powder, 6.75% hydrogenated vegetable oil, 1% fish oil, 0.75% NaCl, 1.5% CaCO₃, and KI (added by spraying) to a level of 1 μg/g.

All of the female rats were bred with young adult males exposed to corresponding environmental conditions. Berkeley native stock rats (3,800 m) were bred after 17 days at high altitude to permit adjustment to the hypoxic environment. Day zero of pregnancy was considered to be the morning when spermatozoa were detected in the vagina. The following investigations were made.

FOOD CONSUMPTION DURING PREGNANCY. To examine the possibility that impairment of fertility at high altitude resulted from reduced appetite, daily food intake was measured from day zero of pregnancy until term in selected animals from each group. Each animal was caged separately and given access to a jar containing a known weight of food. Daily food intake was measured by weighing the food remaining in the jar as well as any residue in the cage. Body weights of the pregnant animals were taken on day zero and day 21 of pregnancy.

REPRODUCTIVE PERFORMANCE. Daily vaginal smears were taken on all groups of animals for 16 days prior to breeding, to record variations in the estrous cycle. On day 21 of pregnancy, the animals were autopsied and the number of fetuses per litter was recorded. The diameter of any resorption sites in the uteri were noted, and the number of corpora lutea in both ovaries was compared with the total number of fetuses and resorption sites.

FETAL MEASUREMENTS. The body weights and body lengths (nose - anus + anus - tail) of the fetuses were recorded. The placentas were cleaned of membranes and weighed. The fetal hearts were dissected free of surrounding tissues and weighed on a torsion balance. Fetal hematocrits were determined with the microhematocrit method.

STATISTICAL METHODS. The t test for non-paired data was applied to determine whether the first-generation high altitude rats differed statistically in their means from the other two groups of animals.

RESULTS

Average food consumption during pregnancy of the sea level control and Berkeley native stock rats at 3,800 m was similar when expressed as g/day (Table 1).

TABLE 1. Comparison of pregnant Long-Evans rats at high altitude (3,800 m) and at sea level

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of rats</th>
<th>Onset wt. g</th>
<th>Absolute (g)</th>
<th>Relative (g/100 g body wt)</th>
<th>Weight gain day 0-21</th>
<th>Daily food intake per rat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls, Berkeley strain</td>
<td>4</td>
<td>295</td>
<td>98</td>
<td>33.2</td>
<td>18.8 ± 1.4</td>
<td>6.4 ± 0.4</td>
</tr>
<tr>
<td>High altitude, Berkeley strain</td>
<td>4</td>
<td>322</td>
<td>62</td>
<td>19.2</td>
<td>16.6 ± 1.1</td>
<td>5.2 ± 0.3*</td>
</tr>
<tr>
<td>High altitude, adapted strain (3,800 m)</td>
<td>4</td>
<td>209</td>
<td>75</td>
<td>35.9</td>
<td>15.1 ± 0.5*</td>
<td>6.8 ± 0.4</td>
</tr>
</tbody>
</table>

Values are means ± SE. *) Significantly different from controls (p < 0.05).