Cyclic Changes in the Oxygen Consumption of the Aorta in Female Rats

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Gonadectomy increases the endogenous oxygen consumption of the aorta in male and female rats. Such enhanced respiration is apparently induced by lack of sex hormones which normally depress the oxidative enzymes of the vessel. Since sexual activity is cyclic in adult female rats and the levels of circulating hormones vary accordingly, further studies were done to correlate the oxygen consumption of the aorta with different phases of estrus.

Methods

SERIES I

Adult white female rats (140 and 150 days of age and weighing 135 to 160 g), fed on the standard diet of the Institute of Physiology, have been used. Light pattern, temperature, and feeding schedules were controlled and kept constant. The determinations were carried out during the afternoon; vaginal smears were performed before sacrifice. The numbers of rats were as follows: diestrus, 15; proestrus, 12; estrus, 14; and metaestrus, 15. The aorta was excised and the adventitia rapidly stripped; the diaphragmatic muscle was removed. Tissues were gently blotted on filter paper, weighed on a torsion balance, rapidly transferred to Warburg vessels, and placed in the bath within three to seven minutes after death of the animals. Approximate weight (wet) of the aorta was 40 mg and of the diaphragmatic muscle 70 mg.

Oxygen uptake was determined in Warburg vessels of 4 to 6 ml capacity; Krebs-Ringer phosphate solution without glucose at a pH 7.4 was used. The vessels were shaken 112/min at 37.4°C; the gas phase was air and 0.2 ml of saturated NaOH solution was placed in the central well. A 15 minute equilibration period preceded the observation period of 60 minutes. The tissues were next put in tared containers and the dry weight determined after 96 hr at 80 ± 2°C. Results expressed as μl O₂/mg dry wt/hr have been compared using Student t-test according to Fisher and Yates.

SERIES II

The experimental procedure has been similar, with the following exceptions: adult white female rats (140 and 170 g) fed on the diet of the Instituto Bacteriológico Malbrán have been used. No predetermined light pattern was followed. Only animals in diestrus were studied. To the incubating solution 0.1% estradiol-17β dissolved in 96% ethanol and adsorbed on 1% crystallized bovine albumin was added. Final concentration of estradiol as well as the number of animals is indicated in tables 1 and 2. Control and experimental flasks contained ethanol (16 mMc) and albumin (1 mg/ml); control vessels did not contain estradiol. Although the water content was not determined in the organs of these rats the percentages found on series I were applied to the wet weights of the present series in order to calculate the rates on a dry weight basis.

Results

As shown in table 1, the endogenous QO₂ of the aorta is significantly higher during diestrus than during other phases of sexual cycle; no differences are present, however, in the diaphragm. As also indicated in table 1, the percentage content of water is constant in both organs throughout the cycle.

Table 2 shows that when estradiol is added in vitro to the aortae of diestrous rats, the endogenous oxygen uptake is depressed, while no changes are induced in the diaphragmatic muscle even by concentrations of hormone ten times as high.

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* The diet of rats from series I consisted of bread, powdered milk, corn, wheat, vegetables, and vitamins A and D. That of series II, consisted of Forramex, Molinos del Río de la Plata, Ltd., which is a mixture of cereals, proteins, and additional vitamins.
TABLE 1

Endogenous Oxygen Uptake of Aorta and Diaphragmatic Muscle of Female Rats (Series I)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Aorta</td>
<td>2.2 ± 0.1</td>
<td>1.0 ± 0.1</td>
<td>0.9 ± 0.08</td>
<td>1.3 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>(73.8 ± 2.8)*</td>
<td>(69.6 ± 1.7)</td>
<td>(72.1 ± 0.9)</td>
<td>(71.5 ± 0.8)</td>
</tr>
<tr>
<td>Diaphragmatic muscle</td>
<td>3.2 ± 0.2</td>
<td>3.1 ± 0.4</td>
<td>3.4 ± 0.3</td>
<td>3.1 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>(77.8 ± 1.0)</td>
<td>(76.7 ± 1.5)</td>
<td>(78.1 ± 0.1)</td>
<td>(78.5 ± 0.3)</td>
</tr>
</tbody>
</table>

P between the oxygen uptake of each phase and diestrus. No differences are present in the water content. *Percentage water content. Number of determinations in brackets, n.s. not significant.

Discussion

The present results indicate that there is a cyclic change in the oxygen uptake of the aorta in female rats in relation to sexual activity. Although another tissue (diaphragmatic muscle) taken as a control showed no such differences, the aorta is not unique in this respect; respiratory changes in sexual structures and the hypophysis are known to occur in connection with the estrous cycle in rats. It is interesting to note that the respiratory rates in the aorta and in the diaphragm were not the same in series I and II. It is possible that differences of strain and of feeding, as well as the presence of ethanol and of albumin in the second series, may account for the lower values. Nevertheless, a clear depression of respiration was demonstrated when estradiol was added in vitro to the aorta of diestrous rats. This may indicate that the cyclic changes found in the aorta during estrus may be secondary to varying estrogen levels. Such an interpretation is in accord with previous work showing that gonadectomy raised aortic oxygen consumption while substitutive therapy and estradiol in vitro depressed it. As reported in the present experiments, the effect on the aorta could not be reproduced in the diaphragm.

The influence of sex hormones on arteries has attracted much attention, since women show much less coronary atherosclerosis than men. In an attempt to modify therapeutically the evolution of the disease in human beings, estrogens have been recommended in pharmacologic dosages. Whether the cyclic changes found in the aortae of female rats are also normally present in human arteries cannot be stated at the present time. If this be the case some consideration may be given to the possibility that a lower incidence of coronary atherosclerosis in women may be related, not only to the presence of female sex hormones, but also to fluctuating hormonal levels.

Summary

The endogenous oxygen consumption of
aorta and of diaphragmatic muscle have been studied in female rats and correlated with different phases of estrus. Cyclic changes of oxygen consumption were demonstrated in the aorta but not in the diaphragm. Estradiol in vitro depressed the endogenous $Q_o_2$ of the aorta from diestrous animals. Possible implications of this work are discussed.

References
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