Energy metabolism in kidney of heat-acclimated hamsters

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Inbar, Ilana, Reuben Chayoth, and Yair Cassuto. Energy metabolism in kidney of heat-acclimated hamsters. Am. J. Physiol. 229(5): 1234-1236. 1975.—Biochemical pathways which are involved in energy metabolism were examined in the kidney of heat-acclimated hamsters. It was found that heat acclimation caused 47% reduction in glucose-6-phosphatase (Glc-6-Pase) activity and 40% lower rate of gluconeogenesis. No changes were found in the activity of hexokinase, glucose-6-phosphate dehydrogenase, pyruvate kinase, lactic dehydrogenase, or in kidney glycogen content. Isolated kidney mitochondria of heat-acclimated hamsters utilized 15% less oxygen than that of controls, but no differences were found in the P/O ratio. Determination of the content of some cytochromes showed a significant reduction in cytochromes c1 and c1, but no difference was found in the content of cytochromes a, a3, and b. These results suggest that the kidney plays a role in the reduction of energy metabolism during the process of heat acclimatization.

Heat acclimation; kidney metabolism; gluconeogenesis

Materials and Methods

Adult (110 ± 10 g) male hamsters (Mesocricetus auratus) were randomly divided into two groups. The first group (control) was maintained at 20-23°C and the other (heat-acclimated) at 34-35°C, with relative humidity between 25 and 40%.

The time of acclimation ranged between 21 and 30 days. The measurements were performed on animals which were fed ad libitum laboratory chow containing 16% protein, 2-4% fat, 9% cellulose, vitamins, and minerals (iodine content = 10 μg/kg) plus succulent vegetables, and freely available water. In the gluconeogenesis experiment, one group of animals was not fed for 24 h before being killed.

The animals were killed by decapitation and then bled. The kidneys were removed immediately and homogenized at 0°C (cortex and medulla) in 0.25 M sucrose. Hexokinase was determined according to Somogyi's technique (25), then hydrolyzed and assayed as glucose with glucose oxidase (15). Gluconeogenesis was determined as follows: 200 mg of kidney slices were incubated at 37°C in 3 ml Kreb's-Ringer bicarbonate buffer (12), with DL-[2-14C]lactate (sp act of 20.7 mCi/mmol). The [14C]glucose produced during the incubation was isolated and determined according to Exton and Park (13).

Kidney mitochondria were isolated as described by Schneider (24). Oxygen consumption and oxidative phosphorylation efficiency (P/O) were measured polarographically at room temperature (22-24°C) according to the method used by Chance and Williams (6), using succinate and glutamate as substrates. The reaction medium for the mitochondria respiration measurements was as previously described (5).

Cytochrome content of the mitochondria was measured with a Cary recording spectrophotometer (7, 16). Proteins were determined by the biuret method (17). Significant differences among group means were calculated according to the Student t test (26).

Results

Measurements of the activity of five enzymes involved in carbohydrate metabolism (Table 1) show that only that
of glucose-6-phosphatase is reduced by 47% in the heat-acclimated animals. Similar reduction is also found in the rate of gluconeogenesis in kidney slices of heat-acclimated hamsters, in both fed and fasted animals. There is no statistical difference between fed and fasted animals in each group. The glycogen content of the kidney is similar in both the control and heat-acclimated animals.

Table 2 shows reduction in the rate of "state 3" respiration, but no change in P/O ratio, in heat-acclimated hamsters compared to the controls.

The concentrations of cytochrome a, a3, and b are not significantly different in both experimental groups, but there is a significant reduction in cytochromes e + e1 content.

**DISCUSSION**

Reduced energy production in liver and in brown fat tissue is known to reduce the metabolic rate (2, 4, 5). This work presents data on several metabolic reactions in the kidney which are reduced by chronic heat exposure. Glic-6-Pase activity, which is known to be present only in liver, kidney, and intestinal mucosa (14), shows a marked change, decreasing to the same extent as found in liver (3, 9). The fact that Glic-6-Pase in kidney and liver is affected in the same manner by chronic exposure to a hot environment suggests that the enzyme is regulated in both tissues in a similar way and that its reduced activity in the kidney has the same physiological aspects as in liver.

Gluconeogenesis was found to be slower in kidney slices of heat-acclimated animals. This result is in agreement with the reduced activity of Glic-6-Pase. No significant difference was found between fed and fasted animals in both control and heat-acclimated groups. Newsholme and Underwood (20) suggest that physiological conditions like fasting or a low-carbohydrate diet are characterized by a high-plasma concentration of fatty acids and ketone bodies known to be a storage of carbohydrates in the liver, may be drawn between the values which have been found for kidney with those of the liver. This polymer, which is known to be a storage of carbohydrates in the liver, may have only minor significance in the kidney.

The results obtained from mitochondria show reduced energy metabolism in the kidney of heat-acclimated hamsters. The reduction of O2 consumption in liver slices of heat-acclimated animals was twice that of kidney slices using succinate or glutamate as substrates (5). Therefore, it seems that liver tissue of such animals is more effective than kidney in lowering metabolic heat production. Results obtained from experiments with mitochondria of brown adipose tissue of heat-acclimated hamsters are not comparable to those of liver or kidney due to the case of different substrates and to lack of response with succinate (22).

**Cytochrome e + e1 content** was found to be significantly lower in kidney mitochondria of heat-acclimated animals as compared with controls. The reduction was 27%, the same as in liver (3). On the other hand, while a marked reduction in the content of a, a3, and b was found in liver mitochondria of heat-exposed hamsters (3), there was no significant change in the kidney. In addition, while cytochromes e + e1 levels in liver and kidney mitochondria of

<table>
<thead>
<tr>
<th>Enzyme activity, µmol/g protein</th>
<th>Control</th>
<th>Heat Acclimated</th>
<th>% Difference</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactic dehydrogenase per min</td>
<td>386.0</td>
<td>335</td>
<td>-13</td>
<td>NS</td>
</tr>
<tr>
<td>Pyruvate kinase</td>
<td>56.3</td>
<td>60.4</td>
<td>+7</td>
<td>NS</td>
</tr>
<tr>
<td>Glucose-6-phosphate dehydrogenase</td>
<td>11.9</td>
<td>10.9</td>
<td>-8</td>
<td>NS</td>
</tr>
<tr>
<td>Hexokinase</td>
<td>10.5</td>
<td>9.3</td>
<td>-11</td>
<td>NS</td>
</tr>
<tr>
<td>Glucos-6-phosphatase</td>
<td>80.4</td>
<td>42.9</td>
<td>-47</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

[14C]Glucose production from [14C]lactate, %/g wet wt per h

| Glycogen content, mg/g wet wt | 103     | 13              | -91          | NS |

Values are means ± SE. Numbers in parentheses are number of animals in each group.

**TABLE 2. State 3 respiration, P:O ratio, and concentration of cytochromes in kidney mitochondria**

<table>
<thead>
<tr>
<th>State 3 respiration, µatoms/mg protein per h</th>
<th>Control</th>
<th>Heat Acclimated</th>
<th>% Difference</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>P:O ratio</td>
<td>2.19</td>
<td>2.00</td>
<td>-8.5</td>
<td>NS</td>
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<tr>
<td>Cytochrome a, µmol/g protein</td>
<td>0.255</td>
<td>0.217</td>
<td>-15</td>
<td>NS</td>
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<tr>
<td>Cytochrome a1, µmol/g protein</td>
<td>0.305</td>
<td>0.247</td>
<td>-19</td>
<td>NS</td>
</tr>
<tr>
<td>Cytochrome b, µmol/g protein</td>
<td>0.234</td>
<td>0.195</td>
<td>-17</td>
<td>NS</td>
</tr>
<tr>
<td>Cytochrome e + e1, µmol/g protein</td>
<td>0.312</td>
<td>0.229</td>
<td>-27</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Values are means ± SE. Numbers in parentheses are number of animals in each group.
heat-acclimated hamsters were reduced, in brown adipose tissue it increased. As for the levels of cytochrome \( a \), \( a_2 \), and \( b \), the results obtained in brown adipose tissue resemble those of liver only (22).

Whether these discussed biochemical changes in the kidney of heat-acclimated hamsters have any influence on kidney functions both in normal physiological conditions and in stress conditions is not yet clear. The clinical implications involved, however, warrant further investigation of the problem.

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REFERENCES


