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Intestinal Absorption in Heat and Cold Acclimated Desert Woodrats (40475)

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During temperature acclimation of mammals, many physiological and biochemical alterations are known to take place at the cellular, tissue, and whole animal level (1–5). However, little is known on the gastrointestinal functions of temperature acclimated animals. The first experiments on intestinal absorption of glucose during heat and cold exposure and hibernation in hamsters, rats, and ground squirrels were reported by Musacchia and his associates (6–8). Further studies on absorption of nutrients are relevant to our understanding of the caloric and nutritional requirements of mammals during acclimation to stressful environmental temperatures. The objective of this study was to measure the effects of heat and cold acclimation of a desert nocturnal rodent i.e., the desert woodrat, *Neotoma lepida,* on the ability of the small intestines to transport glucose using *in vitro* preparations.

Methods. Twenty-nine rats, *Neotoma lepida,* were live-trapped during April and May, 1978 100 km east of Las Vegas, Nevada in the Mohave Desert. All animals were housed in individual cages where water and food were available *ad lib.* Animals were fed oats and succulents (primarily potatoes). Animals were divided randomly into three groups: control, 13 rats; heat-acclimated, 10 rats; and cold-acclimated, 6 rats. The control group was kept in a climatic chamber at 28°, the heat and cold acclimated groups were kept at 35° and 5°, respectively for 4-wk prior to the experiment. The environmental temperatures 28, 35 and 5° were used to represent the thermoneutral zone, heat and cold stresses respectively (10). Lights were adjusted for a 12-hr photoperiod.

The everted intestinal sac provides a useful *in vitro* experimental method for the study of the rate of intestinal absorption of sugars (11). Using this method, the accumulation of glucose against a concentration gradient, i.e., absorption from the mucosal compartment into the serosal compartment, can be demonstrated. Details of this technique and its validity were published earlier (6, 9, 11). Briefly, each rat was bled to death by a heart puncture under light ether anesthesia. The intestine, from 1 cm below the pyloric sphincter to the ileocecal junction was removed and rinsed out with chilled Krebs–phosphate solution. Although it is known that the majority of intestinal uptake occurs in the first few centimeters, the entire intestinal length was used because we are not aware of any data on uptake values in different segments in temperature acclimated animals. The intestine was then cut into segments about 3 to 4 cm long. Each segment was everted and immersed into chilled Krebs–phosphate solution. Each segment was tied from both sides and filled as previously described (11) with about 0.5 ml of 10 m*M* glucose in Krebs–phosphate solution (pH = 7.2). Each of these sacs was immersed in 20 ml of oxygenated Krebs–phosphate–glucose solution (same glucose concentration as inside the sac), each preparation was oxygenated for 1 min and then incubated in a shaking water bath (about 80 oscillations/minute) for 1 hr at 37°. Glucose analysis for the sac content and plasma was analyzed colorimetrically by the improved *O*-toluidine method (12). Glucose absorption was expressed in terms of mg glucose transferred into the serosal compartment per 100 mg tissue (wet weight) per hr. Body weights were measured on all animals once every week. Rectal temperature (Tre) was measured every other day by inserting a quick-registry Schultheis thermometer 25 mm in the rectum.

Results. Data on body weight, food intake, rectal temperature (T_{re}), glucose absorption, and plasma glucose levels are shown in Table I.

Body weight of all the three groups did not change significantly throughout the experimental period. Food intake increased 192%

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TABLE I. INTESTINAL GLUCOSE ABSORPTION AND OTHER RELATED PARAMETERS IN TEMPERATURE ACCLIMATED DESERT WOODRATS.[a]

	Control (28°)	Heat-acclimated (35°)	Cold-acclimated (5°)
Number of animals	13	10	6
Body weight, g (before exposure)	101.0 ± 6.5	91.0 ± 4.4	90.0 ± 5.1
Body weight, g (after 4-week exposure)	103.0 ± 5.1	92.0 ± 3.8	88.3 ± 4.1
Food intake, gram/day	3.8 ± 0.3	2.7 ± 0.3	11.1 ± 1.3
Rectal temperature, °C	36.0 ± 0.2	37.9 ± 0.2	33.0 ± 0.3
Intestinal glucose absorption, mg glucose/100 mg tissue per hr	44.0 ± 4.3	102.3 ± 11.8	49.2 ± 9.8
Plasma glucose, mg/100 ml	109.9 ± 5.2	97.1 ± 8.4	105.4 ± 6.9

[a] ± = SE.

in the cold-acclimated animals and decreased 29% in the heat-acclimated group. The T_{re} of the cold-acclimated group decreased 3.0° and increased 1.9° in the heat-acclimated animals. In all groups intestinal absorption of glucose varied between the different segments throughout the length of the intestines. Glucose uptake values were consistently higher in the upper half of the intestines than the lower half in all groups. In these experiments, intestinal absorption was an actual measurement of serosal transfer of glucose. Therefore, the absorption of each 3–4 segments of one intestine was averaged for each animal. Intestinal absorption of glucose was comparable in the cold-acclimated and the control groups. However, the heat-acclimated group had a significantly ($p < 0.1$) higher intestinal glucose absorption as compared with the other two groups. Plasma glucose concentration did not change significantly between the three groups.

Discussion. Temperature acclimation of the desert woodrat had no effect on body weight. This finding seems to be common in wild rodents (13, 14). On the other hand, cold and heat acclimation decreased body weight in laboratory rats, mice, and hamsters (1, 7, 14, 15). Labile T_{re} was utilized as a mechanism to tolerate cold stress, although food intake increased and was available *ad lib.* At 35°, the desert woodrats were able to adequately regulate their T_{re} at a higher level (35°) and decreased their food intake. Data on intestinal absorption (serosal transfer) of glucose *in vitro* of the cold-acclimated desert woodrat confirmed the earlier reports on the hamster (6, 9). Musacchia and his coworkers (6, 9) found that exposure to cold for 1 to 2 weeks increased intestinal glucose uptake although this elevation did not persist with continued exposure to cold.

The data on the heat-acclimated animals demonstrate a significant alteration in absorptive capacity of the intestine. The increased rate of serosal transfer of glucose in heat-acclimated woodrats may represent a compensating mechanism for the metabolic adjustments, and nutritional needs in a situation where food intake is depressed. Heat acclimation caused reduction in the total amount of glucose transported per sac in both the hamster and the rat (7). In addition, there was no difference in mucosal uptake per gram of tissue in either species. Unlike mucosal uptake, serosal transfer per gram was increased in both species after prolonged heat exposure (7, 8). Also, intestinal rings from heat-acclimated hamsters show increased transport of the non-metabolizable sugar, 3-0 methyl glucose *in vitro* (8). The data on the hamster and the desert woodrat confirm that heat acclimation increases serosal transfer of glucose. However, this finding does not represent an increase in glucose metabolism. Increased serosal transfer may be related to the decreased diffusion barrier, i.e. apparent thinning of the gut wall and decreased metabolism of glucose (7, 8). In our experiments, the intestines of the heat-acclimated group were much thinner than the 28° group but the cold-acclimated group were much thicker. The changes in glucose transport may be related to hormonal changes coupled with changes in food intake. Acclimation of woodrats to heat caused a significant decrease in thyroid function and metabolic rate (16). The depressed thyroid function may, at least in part, explain our data since Levin (17) has shown that hypothyroid rats increased serosal transfer of glucose. The mechanisms involved in alterations of the absorptive capacity of the intestine require further studies.

Summary. The capacity for intestinal absorption of glucose in heat and cold-acclimated desert woodrats was studied using an *in vitro* method. Cold-acclimation had no effect on intestinal serosal transfer, however, heat-acclimation increased the absorptive capacity of the intestine. The alterations in serosal transport of glucose by the intestine may represent a compensatory mechanism for decreased food intake during heat-acclimation.

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