An. Inst. Biol. Univ. Nal. Autón. México 40, Ser. Biol. Exp. (1): 1-6, 2 figs. (1969)

THE INFLUENCE OF COLD AND DEPLETION ON FOOD AND WATER INTAKE *

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ABSTRACT

Twenty four rats were accustomed to feed for 24 hr and fast for 24 hr, alternatively, with water *ad libitum*. Half of them were fed a high carbohydrate diet (HC) and the other half a high fat-non carbohydrate diet (HF). Half of the HC fed, and half of the HF fed, were then exposed to a cold environment (6°C) during the days of feeding; the other half were exposed to cold during the days of fasting. This was done in order to separate the effects of cold during feeding, from the effects of the increased reserve depletion produced by cold the day before feeding. The results showed that the rats eating in the cold had an overall higher food-intake than those fasting in the cold. While this is compatible with the hypothesis that, information from skin, or skin and muscle receptors, is responsible for the increased feeding during cold, it is also compatible with the idea that only active depression of liver glycogen (which produces a "decreasing" glucose concentration in the liver) is the driving stimulus for the increased feeding.

RESUMEN

Un grupo de 24 ratas fue acostumbrado a comer 24 horas y ayunar 24 horas de manera alternada, con agua *ad libitum*. La mitad de ellas se alimentó con una dieta alta en carbohidratos (HC) y la otra mitad con una dieta alta en grasas y exenta de carbohidratos (HF); ambas dietas contuvieron la cantidad necesaria de proteínas, vitaminas y minerales. Los dos periodos experimentales consistieron en exponer 6 ratas alimentadas con HC y 6 con HF a una temperatura de 6°C, durante los días que comieron, permaneciendo a 22°C los días de ayuno. Las otras 6 de cada grupo, se sometieron al proceso inverso, es decir comieron a 22°C y ayunaron a 6°C. El propósito era separar el efecto directo de la bajo temperatura durante la ingestión de alimento del efecto del mayor agotamiento de reservas, sufrido al ayunar a baja temperatura. Los resultados mostraron que las ratas que comieron en el frío aumentaron su ingestión de alimento, mientras que aquellas que ayunaron en el frío disminuyeron su consumo alimenticio. Los resultados fueron compatibles con un efecto directo del frío sobre la ingestión de alimento, pero también fueron compatibles con la idea de que el aumento de ingestión fue debido a la información obtenida por los glucorreceptores hepáticos, acerca del aumento en la velocidad de depleción del glucógeno hepático que produjo el frío.

* Work supported by grant MA-2479 of the Medical Research Council of Canada.
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INTRODUCTION

It is well known that the food intake of the rat is increased when feeding in a colder environment. Several explanations concerning the mechanism of this phenomenon have been offered, one being that information about the skin temperature modifies the activity of the "feeding center" (Brobek, 1960); another being that the decreased temperature of the hypothalamus is the determining factor for the increase in food intake. The increase in food intake of the goat, obtained by local cooling of the anterior hypothalamus has been offered as evidence in support of this hypothesis (Andersson and Larsson, 1961). Unfortunately, opposite results were observed in the rat (Spector *et al.*, 1967). However, in these studies, the changes of hypothalamic temperature at the thermode far exceeded the normal range of brain temperatures (Rampone and Shirasu, 1964). In addition, hypothalamic temperature tends to increase in rats on exposure to a cold environment (Lomax *et al.*, 1964).

A more recent hypothesis is that the information of temperature from the skin receptors might be compared in the hypothalamus to the temperature information from deeper muscles, this difference being a reflection of the insulation, which is dependent on the quantity of subcutaneous fat available (Stevenson, 1964).

These hypothesis are opposed by one stating that the depletion of the reserves produced by the increased energy expenditure during cold exposure might be the actual stimulus for the increased feeding. The following study was an attempt to separate the effects on food-intake of cold *per se* (information from skin themoreceptors), from the effects of the depletion of energy reserves induced by cold exposure.

METHODS

Twenty four male Wistar rats housed in individual wire cages with 12 hours light and 12 hours dark were divided into two groups, one fed High Carbohydrate Diet (HCD: 70.6% sucrose, 20.8% protein, 4.6% fat by weight), the other High Fat Diet Non-Carbohydrate (HFD; 20.7% protein, 35.0% fat by weight). Both diets contained adequate vitamins and minerals. The rats were alternately fed and fasted, each for a 24-hour period. The initial adaptation period lasted for 14 days at an ambient temperature of $22 \pm 2°C$.

The experimental periods consisted of the feed-fast cycle, in addition to which the rats were divided in two groups (*A* and *B*), each consisting of 12 rats, six being fed the HCD and six being fed the HFD. In the first experimental period (E-I), group *A* was always fed in the cold ($6 \pm 2°C$) and fasted at normal temperature ($22 \pm 2°C$), while group *B* was always fed at 22°C and fasted at 6°C. This procedure was continued for 14 days, after which the adaptation schedule (where all the animals were fed and fasted at 22°C) was resumed for five days. The groups were then reversed for the second experimental period (E-II), i.e. group *A* was fed at 22°C and fasted at 6°C, while group *B* was fed at 6°C and fasted at 22°C. This period lasted for 27 days.

Water intakes were measured daily; food intakes were measured every feed day, i. e. every other day. Spillage was collected and subtracted from the apparent food intake during E-II. Body weight was measured at various times throughout the experiment.

RESULTS

It can be seen from Figs. 1 and 2 that the food intake was similar for both groups in the adaptation period. Although it appears that the HFD-fed rats ate slightly more than those fed the HCD, this difference was due mostly to spillage. When the spillage was subtracted the corrected food intakes of the HFD-fed rats more closely resembled that of the HCD-fed rats.

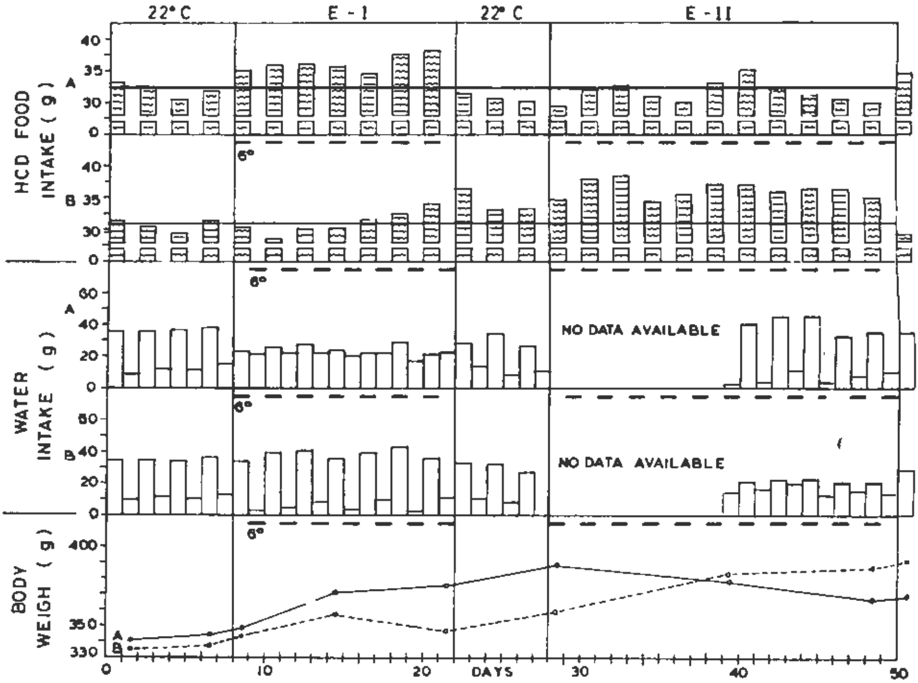

Fig. 1. Food-intake, water intake did body weigth of rats feed a high carbohydrate diet (HCD) and subjected to a 24h feeding-24h fasting schedule. *A* and *B* are two groups of 6 rats each. During the experimental periods (E-I and E-II), one group fed at 6°C (days marked with a black horizontal bar) and fasted at 22°C, while the other group fed of 22°C and fasted at 6°C.

On commencement of the experimental periods (E-I and E-II) those rats fed in a cold environment increased their food consumption, and maintained it increased throughout this phase, while those rats fed at room temperature (and fasted in the cold) decreased their food intake; only after several days of subjection to this regimen did they begin to increase their average food-intake.

After each experimental period, when all the rats were fed and fasted at 22°C, the food intakes decreased and the group averages approached each other again.

The body weight of all rats increased similarly during the adaptation period, however during the experimental periods, the body-weight increases of the cold-fed rats exceeded that of the animals fed at room temperature, which lost weight.

The cyclic variation of the water in-

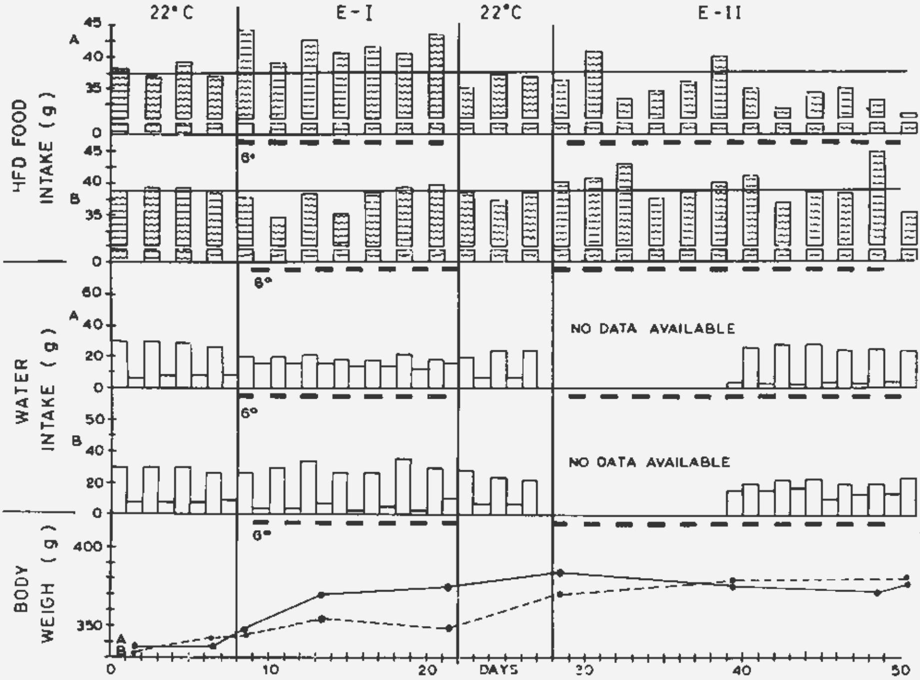

Fig. 2. Same as Fig. 1 but in rats fed a high fat-non carbohydrate diet (HFO).

take is shown to be the result of the intermittant feeding i.e. much less water is ingested on fasting than on feeding days. During E-I and E-II this oscillation was greatly reduced in the cold-fed animals and somewhat increased in those fed at the normal temperature, and fasted in the cold.

DISCUSSION

The results of the present study are compatible with the hypothesis that information from skin temperature receptors (or the comparison of information from the skin and muscle receptors) is the driving force producing the increased food intake during cold exposure (Brobeck, 1960; Stevenson, 1964) However, another possible interpretation is that the actual stimulus for feeding is not the quantity of reserves available, but rather the rate of depletion of certain reserves, mainly glycogen (Russek and Stevenson, in preparation). This followed from the hypothesis (Russek, 1963) that an important factor determining feeding is the rate of change of the intracellular glucose in the liver, which is informed to the central nervous system by glucoreceptors localiced in the hepatic parenchyma (Niijima, 1969). The frequency of firing from these receptors would be correlated with the rate of glucose utilization and therefore would be increased during cold exposure. This then, would explain the overall increased food intake for those animals eating in the cold.

Those animals feeding at normal temperature (fasting in the cold) were not subjected to an increased rate of depletion while food was available, and therefore did not eat as much as those feeding in the cold. It would appear that the effects of increased depletion in the rats fasting in the cold was not sufficient to produce the necessary compensation during the next day's feeding, which is evidenced by their loss of weight.

As the intermittent exposure to cold progressed, the rats showed a tendency to increase their food intake, achieving at times, values close to those of the rats feeding in the cold. This may be due to either the effect of a stronger depletion accumulated over several days, or to a process of "learning-to-predict" the depletion of the following day.

One other interesting observation was that while the previous day's depletion of energy reserves, increased by cold, was not compensated for by an increased food intake the next day, the depletion of fluids produced an observable effect on the water intake of the subsequent day; the animals fasting in the cold showed a decreased water intake (as compared to their water intake during the adjustment period); the following day they compensated for it by an increased water intake. The opposite was observed with those animals feeding in the cold, i.e. they drank less water while feeding, as a result of the cold compensating for this incurred deficit by drinking more when fasting.

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