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Dietary Obesity in Hamsters: Effects of Age, Fat Source, and Species

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Three experiments further characterized high-fat diet-induced increases in body weight and thermogenic capacity in hamsters. The first experiment demonstrated that fat-fed weanling Syrian hamsters rapidly gain weight and become obese without overeating. This enhanced metabolic efficiency is accompanied by increased growth of brown adipose tissue. These responses to high-fat diets are similar to those of adult Syrian hamsters and contrast with the finding that weanling rats do not become obese when fed similar diets. The second experiment showed that these responses are not unique to any one fat source. Hamsters fed diets enriched wtih shortening, corn oil, or medium-chain triglycerides (MCT) display elevated body weight gains, feed efficiencies, brown and white adipose tissue weights, and thermogenic capacities. MCT did not stimulate thermogenesis and decrease body weight in Syrian hamsters as they do in rats. Like Syrian hamsters, Siberian hamsters exhibited precise caloric regulation and did not overeat on a high-fat diet. However, the high-fat diet did not affect body weight, feed efficiency, or brown adipose tissue in Siberian hamsters as it did in Syrian hamsters. In conclusion 1) High-fat diets increase metabolic efficiency and thermogenic capacity in weanling and adult Syrian hamsters. 2) These effects are seen with a variety of fat sources. 3) Siberian hamsters do not respond to a high-fat diet in the same ways that Syrian hamsters do.

Key words: hamsters, obesity, high-fat diet, brown adipose tissue, thermogenesis

INTRODUCTION

Syrian hamsters (*Mesocricetus auratus*) fed a high-fat diet increase their rates of weight gain and rapidly become obese. Compared with hamsters fed a high-

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carbohydrate rodent chow (Purina #5001), fat-fed animals typically do not overeat. Instead, the increase in weight gain and the obesity are due to a high-fat diet-induced decrease in energy expenditure [Wade, 1982, 1983]. Resting thermogenesis (O_2 consumption) is significantly lower in fat-fed hamsters than in animals fed chow or chow plus a 32% sucrose solution [Wade, 1982]. The increased metabolic efficiency of fat-fed hamsters is not due to changes in voluntary exercise [Wade, 1982; Ruby, Bartness, and Wade, unpublished data].

Interscapular brown adipose tissue wet weight, DNA content, and protein content are significantly increased in male and female hamsters fed a high-fat diet [Wade, 1982, 1983]. These increases in the amount of brown adipose tissue are accompanied by an enhanced capacity for thermogenesis (norepinephrine-induced O_2 consumption [Wade, 1982]. Thus, while fat-fed hamsters exhibit a decrease in actual energy expenditure, they have more brown adipose tissue and an increased thermogenic capacity compared with chow-fed animals.

It has been suggested that these diet-induced increases in metabolic efficiency and thermogenic capacity would be beneficial in preparing hamsters for winter. Consistent with this possibility are the findings that the effects of high-fat diets on brown adipose tissue, thermogenic capacity, energy balance, and adiposity are exaggerated by exposure to short photoperiods or by treatment with the pineal hormone, melatonin [Wade, 1983; Bartness and Wade, unpublished data].

The following experiments further characterize this form of dietary obesity in hamsters. The first two experiments examine the effects of age and dietary lipid source. The third experiment looks at the effects of a high-fat diet on the dwarf Siberian hamster (*Phodopus sungorus sungorus*).

MATERIALS AND METHODS

Syrian hamsters were purchased from Charles River Breeding Laboratories (Wilmington, MA), and Siberian hamsters were bred in our laboratory (breeders generously provided by Dr. Bruce Goldman). All animals were housed in stainless steel wire-bottom cages. Room temperature was maintained at 23 ± 2°C, and lights were on from midnight to 1600 hr (LD, 16:8) unless noted otherwise. During baseline periods hamsters had ad libitum access to tap water and Purina Rodent Chow pellets (#5001, 3.4 kcal/g). Animals were divided into experimental groups matched for mean baseline caloric intake, body weight, and body weight gain. Food intake and body weight were measured to the nearest 0.1 g once or twice a week.

The experimental diets were: 1) Chow: Purina chow pellets; 2) High-fat diet: 2 parts powdered Purina chow and 1 part vegetable shortening, 5.3 kcal/g; 3) Long-chain triglyceride diet: 73% (by weight) powdered Purina chow and 27% corn oil, 4.9 kcal/g; 4) Medium-chain triglyceride diet: 73% powdered Purina chow, 2% corn oil, 25% medium-chain triglyceride oil (Mead-Johnson, Evansville, IN), 4.9 kcal/g. The mixed diets were presented in 125-ml glass jars fastened to the fronts of the animals' cages.

At the end of each experiment animals were killed with an overdose of sodium pentobarbital (Nembutal). Interscapular brown adipose tissue and gonadal white adipose tissue were dissected and weighed to the nearest mg. In Experiment 1 interscapular brown adipose tissue protein and DNA content was measured in ethanol-washed tissue homogenates by the methods of Lowry et al. [1951] and Burton [1956],

respectively. All data were ana
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EXPERIMENT 1: EFFECT

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Procedure

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Results

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Procedure

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respectively. All data were analyzed with analyses of variance followed by Newman–Keuls post hoc tests where appropriate.

EXPERIMENT 1: EFFECT OF AGE

High-fat diets readily induce obesity in adult rats and hamsters [Kanarek and Hirsch, 1977; Wade, 1982, 1983], but these same diets are ineffective in weanling rats. That is, they do not increase body weight or induce obesity until some time after 60 days of age [Lemonnier, 1972; Simson and Gold, 1982]. High-fat diet-induced changes in metabolic efficiency and thermogenic capacity may be of value in readying hamsters for winter. Thus, if the effects of high-fat diets are delayed in hamsters, as they are in rats, hamsters born at the end of the breeding season would be at a disadvantage compared with animals born earlier in the breeding season. The first experiment examines the effects of a high-fat diet on weanling hamsters.

Procedure

Twenty-four male and 24 female Syrian hamsters arrived in the laboratory at 21 days of age. Baseline food intake and body weight measures were taken during days 23–25. Starting at 25 days of age, half the animals of each sex were fed the high-fat diet (2 parts chow, 1 part shortening), and half were fed chow pellets. All animals were killed at 60 days of age.

Results

Fat-fed hamsters of both sexes exhibited significant increases in body weight gain ($P < 0.05$) and feed efficiency ($P < 0.01$) (g body weight gain/kcal eaten) within one week (Fig. 1). These differences persisted until the animals were killed at 60 days of age. The fat-fed hamsters rapidly adjusted for the increase in caloric density and did not overeat (Fig. 1).

Feeding the high-fat diet signficantly increased interscapular brown adipose tissue wet weight, protein content, and DNA content (all P's < 0.01) in both sexes (Fig. 2). Parametrial and epididymal white adipose tissues were also heavier in fat-fed hamsters (all P's < 0.01) (Table 1).

EXPERIMENT 2: EFFECT OF FAT SOURCE

The obesity of fat-fed hamsters is due principally to diet-induced decreases in energy expenditure [Wade, 1982]. However, this phenomenon has only been demonstrated using one fat source, vegetable shortening. It would be useful to determine whether similar effects are obtained with other fats. Of particular interest would be the effects of medium-chain triglycerides (MCT). MCT are metabolized differently than long-chain triglycerides (LCT, e.g., shortening or corn oil) in experimental animals and human beings [Bach and Babayan, 1982; van den Brandt and Trayhurn, 1981]. Most significant is the finding that relative to LCT-fed controls, MCT-fed rats show significant increases in thermogenesis and decreases in body weight and adiposity [Baba et al., 1982].

Procedure

The second experiment was designed to determine whether an MCT-rich diet would increase energy expenditure and reduce body weight relative to LCT-fed

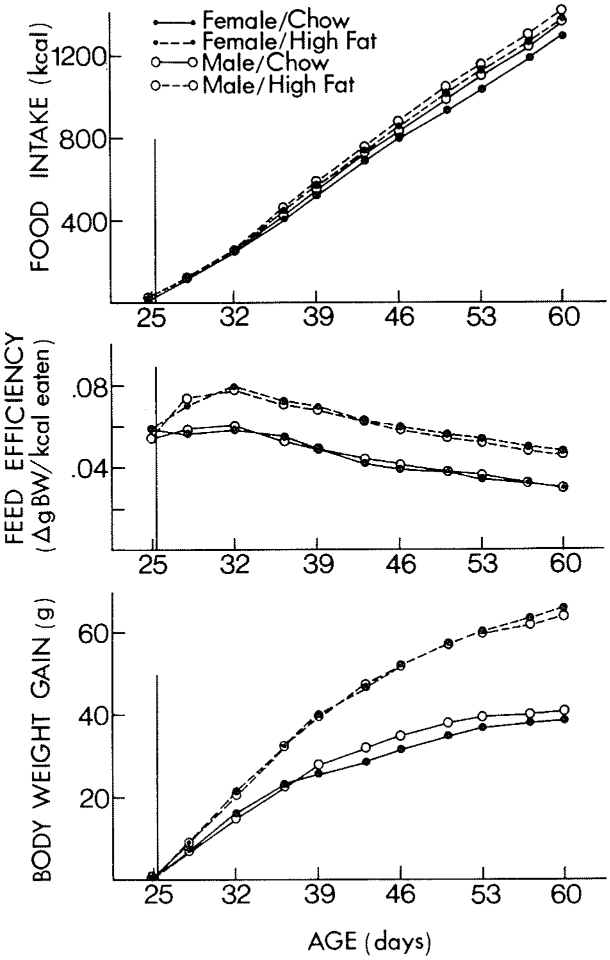

Fig. 1. Cumulative food intake, body weight gain, and feed efficiency (g body weight gain/kcal eaten) of male and female Syrian hamsters fed Purina chow or a high-fat diet from 25 to 60 days of age.

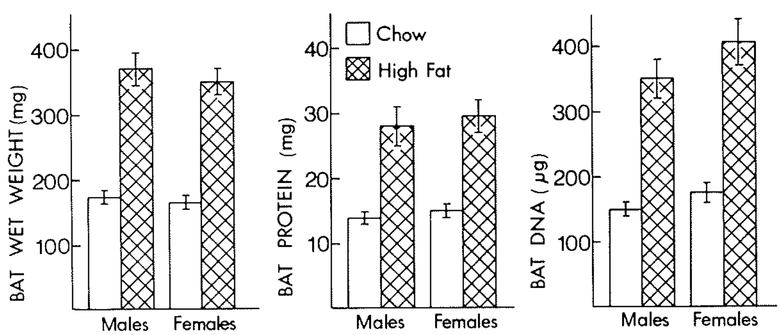

Fig. 2. Interscapular brown adipose tissue wet weight, protein content, and DNA content of male and female Syrian hamsters fed Purina chow or a high-fat diet from 25 to 60 days of age.

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TABLE 1. Gonadal Fat Pad Weights (mg) of Syrian Hamsters Fed Chow or High-Fat Diet From 25 to 60 Days of Age (Mean ± S.E.M.)

	Chow	High-fat
Males	654 ± 71	1750 ± 108
Females	388 ± 42	1424 ± 97

hamsters. Three groups of male hamsters (N = 10 each group) were fed chow, an MCT-rich diet, or an LCT-rich diet for 4 wk.

Results

Both MCT- and LCT-fed hamsters showed significant increases in body weight gain, feed efficiency, interscapular brown adipose tissue weight, and epididymal white adipose tissue weight (all P's < 0.01) (Fig. 3). These findings replicate earlier work using shortening as the fat source [Wade, 1982, 1983]. Unlike our previous work, the fat-fed hamsters in the present experiment overate by ~20% compared with chow-fed controls ($P < 0.01$) (Fig. 3).

Thermogenic capacity (norepinephrine-stimulated O_2 consumption [Wade, 1982]) was measured in 3 hamsters from each group. Mean thermogenic capacity was 40–50% higher in MCT- and LCT-fed hamsters than in controls. Among these 9 animals there was also a strong positive correlation between brown adipose tissue weight and norepinephrine-induced O_2 consumption ($r = 0.93$, $P < 0.01$).

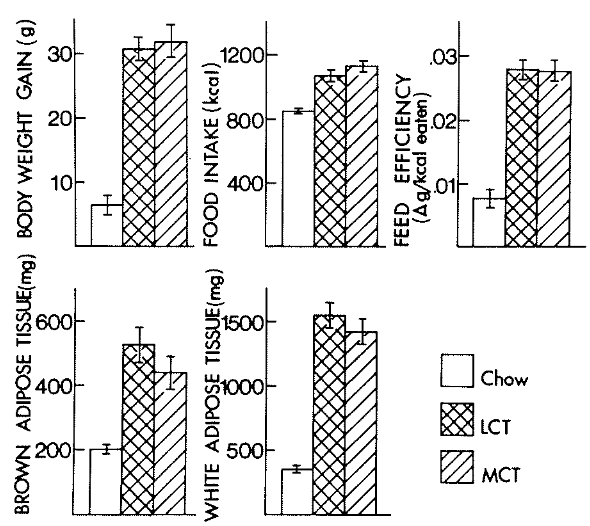

Fig. 3. Body weight gain, food intake, feed efficiency, interscapular brown adipose tissue weight, and epididymal white adipose tissue weight of male Syrian hamsters fed Purina chow or diets enriched with medium-chain triglyceride oil (MCT) or corn oil (LCT) for 4 wk.

EXPERIMENT 3: SIBERIAN HAMSTERS

There are numerous differences between rats and hamsters in their responses to high-fat diets [Wade, 1982, 1983; Experiments 1 and 2]. It would be of interest to see whether other species of hamsters respond to high-fat diets as the Syrian hamsters do. For our comparisons we chose the Siberian (Djungarian) hamster (*Phodopus sungorus sungorus*). Although the two species have similar digestive tracts, Syrian and Siberian hamsters show very different body weight responses to changes in photoperiod [Hoffmann, 1979], treatment with melatonin [Hoffmann, 1979; Wade and Bartness, unpublished data], and gonadectomy [Wade and Bartness, unpublished data]. This experiment was done in two parts: once with animals in a long photoperiod when Siberian hamster body weight is maximal and once in a short photoperiod when body weight is reduced [Hoffmann, 1979].

Procedure

In part 1, 16 female (mean body weight: 36 g) and 18 male (mean body weight: 41 g) Siberian hamsters were housed in a long photoperiod (LD, 16:8). Half of the animals of each sex were fed chow and half were fed high-fat diet (shortening and powdered chow) for 5 wk.

In part 2, 24 male Siberian hamsters were moved from the long photoperiod to a short photoperiod (LD, 8:16, lights on at 0400 hr) in order to induce a weight loss. After 10 wk in the short photoperiod, half of the hamsters were fed the high-fat diet and half continued to eat chow. At the same time, half of each diet group (N = 6 each group) was returned to the long photoperiod. All hamsters were killed after 10 wk on the two diets and two photoperiods.

Results

High-fat diet had no effect on caloric intake, body weight, interscapular brown adipose tissue weight, or gonadal white adipose tissue weight in male and female Siberian hamsters (Table 2) housed in a long photoperiod. Nor was there any effect of diet on reduced-weight hamsters maintained in a short photoperiod (Fig. 4, Table 3). However, as reported previously [Hoffmann, 1979], switching Siberian hamsters from a short photoperiod to a long photoperiod induced a substantial weight gain (Fig. 4). Although this photoperiod-induced weight gain was accelerated in fat-fed hamsters, final body weight was unaffected by diet (Fig. 4). Long photoperiods increased caloric intake of hamsters fed both diets. However, food intake did not change until body weight had increased significantly (Fig. 4).

TABLE 2. Body Weight Gain, Caloric Intake, Interscapular Brown Adipose Tissue Weight, and Gonadal White Adipose Tissue Weight of Siberian Hamsters Fed Chow or High-Fat Diet (Mean ± S.E.M.)

	Males		Females	
	Chow	High-fat	Chow	High-fat
Body weight gain (g)	3.5 ± 0.9	4.0 ± 1.1	2.7 ± 0.6	3.2 ± 0.7
Food intake (kcal/day)	18.3 ± 0.7	18.5 ± 0.6	18.1 ± 0.9	17.8 ± 0.8
Brown adipose tissue (mg)	255 ± 30	238 ± 16	299 ± 20	283 ± 24
White adipose tissue (mg)	501 ± 49	505 ± 40	167 ± 17	168 ± 21

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Females	
Chow	High-fat
2.7 ± 0.6	3.2 ± 0.7
18.1 ± 0.9	17.8 ± 0.8
299 ± 20	283 ± 24
167 ± 17	168 ± 21

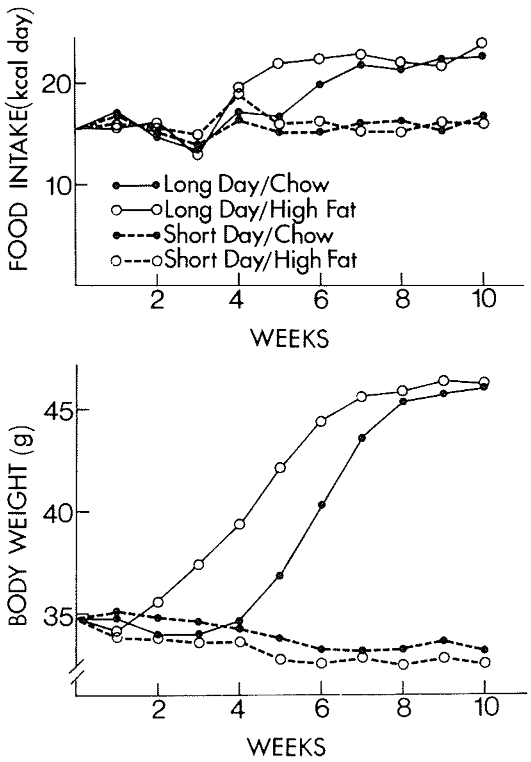

Fig. 4. Food intake and body weight of male Siberian hamsters fed Purina chow or a high-fat diet. Half the animals in each diet condition were housed in a short photoperiod (LD, 8:16), and half were switched from the short photoperiod to a long photoperiod (LD, 16:8) at the beginning of the experiment.

TABLE 3. Effect of Diet and Photoperiod on Interscapular Brown Adipose Tissue and Epididymal White Adipose Tissue in Siberian Hamsters (Mean ± S.E.M.)

	Long photoperiod		Short photoperiod	
	Chow	High-fat	Chow	High-fat
Brown adipose tissue (mg)	200 ± 21	213 ± 32	155 ± 26	136 ± 9
White adipose tissue (mg)	482 ± 16	509 ± 62	149 ± 58	171 ± 31

Diet had no effect on brown or white adipose tissue weights, but hamsters housed in the long photoperiod had heavier fat pads than short photoperiod animals ($P < 0.05$) (Table 3). The effect of photoperiod on interscapular brown adipose tissue is abolished if the tissue is expressed relative to body weight. The effect on epididymal white adipose tissue is significant whether expressed as relative or absolute weight (all P's < 0.05).

DISCUSSION

These three experiments have enabled us to extend our species comparisons of the effects of high-fat diets on rodent energy balance. Experiment 1 demonstrated that, unlike rats, weanling Syrian hamsters respond immediately to high-fat diets with increases in body weight gain and feed efficiency. Just as adult hamsters do, the fat-fed weanlings increased body weight and adiposity without overeating. In addition, brown adipose tissue weight, protein content, and DNA content were elevated in fat-fed hamsters killed at 60 days of age, as in adult hamsters. In fact, the only difference we detected between weanlings and adult hamsters is that there was no sex difference in the weanlings' response. (Adult females are more responsive to high-fat diets than males [Wade, 1983].) This finding is not surprising in view of the fact that in Charles River hamsters the sex difference in body weight does not appear until after ~80 days of age (growth charts from Charles River).

The rapid responses of male and female weanling hamsters to the dietary manipulations are consistent with the hypothesis that high-fat diet effects on Syrian hamster energy metabolism and thermogenic capacity are of some use in preparation for winter. If the responses were delayed, hamsters born late in the breeding season would be at a disadvantage as winter approaches.

The results of Experiment 2 indicate that the response of Syrian hamsters to high-fat diets is not unique to diets made from shortening. High-fat diets made from corn oil (LCT) and MCT oil produced results indistinguishable from those obtained with shortening-based diets. Hamsters fed corn oil or MCT oil diets showed a modest hyperphagia, unlike our previous findings using shortening [Wade, 1982, 1983]. However, we now find that on occasion hamsters fed shortening-based high-fat diets will overeat [Bartness and Wade, unpublished data]. It is not clear why fat-fed hamsters are mildly hyperphagic some times but not others.

Rats fed MCT-rich diets show increased thermogenesis and decreased body weight and adiposity compared with LCT-fed animals [Baba et al., 1982]. In contrast, hamsters fed MCT- and LCT-rich diets had indistinguishable changes in weight, adiposity, thermogenesis, and brown adipose tissue weight. Once again rats and Syrian hamsters respond differently to dietary lipids.

Finally, Syrian and Siberian hamsters differ in their responses to a high-fat diet. The Siberian hamsters showed precise regulation of caloric intake and did not overeat on the high-fat diet, much as the Syrian hamsters do. However, these dietary manipulations had no effect on body weight, adiposity, brown adipose tissue weight, or feed efficiency as they do in Syrian hamsters. Given that we know relatively little about the regulation of feeding and body weight in Siberian hamsters, it would be premature to speculate about the significance of this species difference in responsiveness to high-fat diets. However, it is worth noting that Syrian and Siberian hamsters do show opposite body weight responses to changes in photoperiod [Hoffmann, 1979; Wade and Bartness, unpublished data] and gonadectomy [Wade and Bartness, unpublished data]. Comparisons with other species of hamsters should be informative.

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