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# Body Weight, Food Intake and Energy Regulation in Exercising and Melatonin-Treated Siberian Hamsters[1]

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BARTNESS, T. J. AND G. N. WADE. *Body weight, food intake and energy regulation in exercising and melatonin-treated Siberian hamsters*. PHYSIOL BEHAV 35(5) 805–808, 1985.—The coupling among energy intake, storage, and expenditure was examined in male Siberian hamsters (*Phodopus sungorus sungorus*) given access to running wheels for 14 weeks. Half of the hamsters were injected with melatonin in a schedule that mimics the effects of short photoperiods by decreasing body weight, carcass lipid content, and testis weight. The exercise-induced body weight increases which are seen in Syrian hamsters (*Mesocricetus auratus*) were not found in Siberian hamsters. Instead, the Siberian hamsters maintained their body weights, compensating for the increased energy demands of exercise by increasing their food intakes. Exercise did not affect carcass composition. Melatonin treatment decreased food intake and carcass lipid stores but did not affect voluntary exercise. The previously reported decrease in testis weight was seen in all melatonin-treated hamsters, but the stimulation of brown adipose tissue growth was not. Thus, exercising Siberian hamsters, unlike exercising Syrian hamsters, appear to exhibit a tight coupling among energy intake, storage, and expenditure.

Hamsters Exercise Melatonin Brown adipose tissue

A tight coupling among energy intake, storage, and expenditure is not universally observed in all species under all conditions. For example, voluntary wheel-running is an energetically demanding behavior which is performed by many small mammals [9] but responded to differently in terms of food intake and energy storage (for review see [5]). Rats decrease their food intake with access to running wheels [7, 16, 20] and initially decrease their body weight [3]. In sharp contrast, Syrian hamsters (*Mesocricetus auratus*) increase their food intake, body weight, and somatic growth when given access to horizontal discs [4] or vertical running wheels [2] (but cf. [23]).

Another example of an uncoupling of energy intake, storage, and expenditure is that Syrian hamsters become obese without overeating when given a high-fat diet [1, 2, 31–33, 35], whereas rats overeat when fed a similar diet [8,26]. Finally, Syrian hamsters, unlike rats, also exhibit photoperiod-induced changes in body weight and body fat without altering their food intake [32,35]. These short photoperiod-induced increases in body weight and adiposity are mimicked by daily afternoon injections of the pineal gland hormone, melatonin [1,35].

The purpose of the present experiment was to examine the effects of voluntary exercise on the coupling of energy intake, storage, and expenditure in Siberian hamsters (*Phodopus sungorus sungorus*), a species which exhibits opposite body weight responses to short photoperiods and afternoon melatonin injections (body weight and carcass fat losses [34]) than Syrian hamsters (body weight and carcass fat gains [1,35]). Thus, Siberian hamsters treated with melatonin will be challenged with the increased energy demands of wheel running at a time when their energy stores (carcass lipid) are decreased. In order to obtain metabolic fuel homeostasis, melatonin-injected exercising hamsters should either: (a) increase their food intake to match the increased energy demands of exercise, especially in light of their decreasing energy stores due to the melatonin treatment [34], or (b) decrease their exercise, perhaps in proportion to their energy reserves (i.e., body fat). Unchanged food intake or exercise levels in melatonin-injected Siberian hamsters should produce an exaggerated depletion of lipid energy reserves.

## GENERAL METHOD

### *Animals*

Fifty-seven adult male Siberian hamsters (*Phodopus sungorus sungorus*) derived from breeding stock generously

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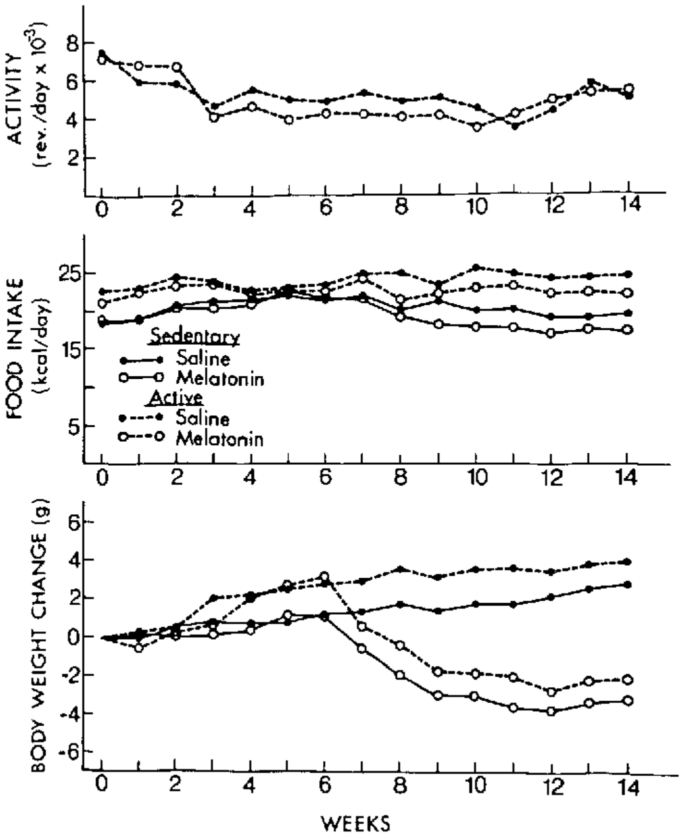


FIG. 1. Running wheel activity (top), food intake (middle), and body weight change (bottom) of male Siberian hamsters given access to running wheels (active) or housed in cages (sedentary) for 14 weeks. Half of the animals in each group received daily afternoon injections of melatonin (12.5 μg SC), and half received vehicle injections.

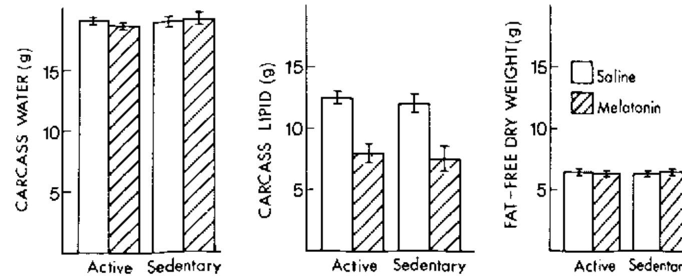


FIG. 2. Carcass composition of Siberian hamsters in Fig. 1.

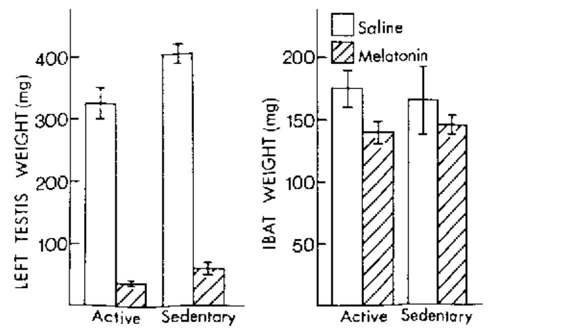


FIG. 3. Left testis weight and interscapular brown adipose tissue (IBAT) weight of Siberian hamsters in Fig. 1.

provided by Dr. Bruce Goldman were housed singly in stainless-steel, wire-bottom (6 mm mesh) hanging cages (sedentary) or in vertical activity wheels (active) one meter in circumference (Wahmann LC-34). Purina laboratory rodent chow (No. 5001, 34.4 kcal/g) and tap water were provided ad lib. Room temperature (22±1°C) and photoperiod (LD, 16:8, lights on at 0100 hr) were held constant throughout the experiment. Body weight and food intake (corrected for spillage and pouching) were measured to the nearest 0.1 g at weekly intervals. Activity (revolutions/day) was recorded daily just prior to lights-out. Half of the animals in the sedentary and active groups were injected daily with melatonin (Sigma Chemical Co., 12.5 μg/day in 0.05 ml 5% ethanol-0.15 M NaCl vehicle) or the vehicle alone 3 hr prior to lights-out for 14 weeks. This injection paradigm mimics the naturally occurring changes in body weight and composition, food intake, and reproductive condition in sedentary Siberian hamsters housed in short photoperiods (LD, 8:16) [34].

### *Carcass Composition, Brown Adipose Tissue, and Testis Weights*

Terminal carcass composition was measured by the method of Leshner *et al.* [18]. The shaved, eviscerated carcasses were dried to a constant weight at 70–75°C. The dehydrated carcasses were finely ground in a blender, and a homogeneous sample (~0.5 g) was taken. Lipid was extracted from the samples with petroleum ether to a constant weight. The remaining sample was weighed and termed fat-free dry weight.

Interscapular brown adipose tissue (IBAT) was dissected away from the surrounding white adipose, muscle, and connective tissues and weighed to the nearest mg. The left testis was removed and weighed to the nearest mg.

### *Data Analyses*

Between-group comparisons were made using two-way analyses of variance or *t*-tests. Results were considered statistically significant if $p<0.05$.

## RESULTS

Treatment with melatonin did not affect running wheel activity (Fig. 1, upper panel). Food intake was increased in active hamsters relative to the sedentary controls across the entire 14-week experiment ($p<0.05$) (Fig. 1, middle panel). For the first 8 weeks of the experiment, melatonin had no effect on food intake. But during the last 6 weeks, the melatonin-treated hamsters ate significantly less than their vehicle-treated counterparts, regardless of exercise condition ($p<0.05$) (Fig. 1, middle panel).

There was no significant effect of exercise on body weight. However, melatonin treatment decreased body weight 7 weeks into the experiment and continued through the final body weight measure at 14 weeks ($p<0.05$) (Fig. 1, bottom panel). There was no interaction between melatonin treatment and exercise condition.

Neither carcass water content nor fat-free dry weight was affected by either experimental manipulation (Fig. 2, left and right panels). Carcass lipid content was unaffected by exercise but was significantly decreased by melatonin treatment in both exercise conditions ($p<0.01$) (Fig. 2, center panel). Given the results of the carcass analyses, it appears as though the consistent, but statistically nonsignificant, increases in terminal body weights among the active hamsters (both melatonin- and vehicle-treated) must have been due to increased weight of the full gastrointestinal tract (Fig. 1). (Recall that the active hamsters ate significantly more than the sedentary animals.) Indeed, the shaved-eviscerated carcass weights of exercising and sedentary hamsters were not different ($r>0.05$).

As expected, melatonin treatment induced testicular regression ($p<0.01$) (Fig. 3, left panel). We also found an unanticipated decrease in testis weight in the active versus sedentary vehicle-treated hamsters ($p<0.05$). A similar trend was seen among the melatonin-treated animals, but this difference did not reach statistical significance.

Melatonin treatment interacted with the effects of exercise on IBAT weight ($p<0.05$) (Fig. 3, right panel). That is, there was no effect of exercise or melatonin alone, but the melatonin-injected, active hamsters had significantly less IBAT than the vehicle-treated controls.

## DISCUSSION

The results of this experiment suggest that the coupling of energy intake and expenditure in exercising Siberian hamsters is quite tight, despite the added challenge of reduced carcass lipid (energy) stores as a consequence of melatonin treatment. Melatonin treatment decreased body weight and carcass lipid levels in exercising hamsters without affecting activity level and did so to the same extent as in the sedentary animals. The increased energetic demands of wheel running were offset by an increase in food intake which resulted in no significant differences in terminal body weight and composition between the melatonin-treated, active and melatonin-treated, sedentary groups. The vehicle-injected hamsters also increased their food intake and maintained body weights and carcass composition almost identical to the sedentary controls, even though they did not experience the extra energetic challenge of depleted lipid stores that occurred for the exercising, melatonin-injected hamsters.

These data are consistent with our previous report that Siberian hamsters do not overeat or become obese when fed a calorically dense, high-fat diet [33]; thus, energy intake matched energy output, as evidenced by their unchanging body weight. In contrast, Syrian hamsters do not regulate their body weight very precisely. For example, although Syrian hamsters do not overeat when fed a high-fat diet, they become obese [1, 2, 31–33, 35]. Exercising Syrian hamsters show increased body weight [3, 4, 5], however in the present study, Siberian hamsters did not show an exercise-induced increase in body weight. It appears that only rarely do Syrian hamsters make apparent adaptive responses to match energy intake with energy expenditure. Specifically, when energy demands are extreme, such as is seen in diabetic [25] or cold-exposed [24] exercising Syrian hamsters, they decrease their wheel-running and increase their food intake.

Treatment of Siberian hamsters with exogenous melatonin has been reported to increase brown adipose tissue mass [12]. Once again [34], we have failed to find a stimulatory effect of melatonin on brown adipose tissue wet weight. Perhaps this is because we only weighed one brown fat pad (interscapular), and it is unclear which brown adipose tissue depot(s) were measured in the original report [12]. It is unlikely that our lack of effect is due to our use of daily melatonin injections [34] versus constant-release subcutaneous implants [12]. We have found no effect of subcutaneous silastic implants of melatonin on IBAT wet weight (Bartness and Wade, unpublished data; Bartness and Goldman, unpublished data).

However, it is clear that in Siberian hamsters melatonin treatment or exposure to short photoperiods does enhance cold resistance [14,28], ostensibly in part via enhanced brown adipose tissue thermogenesis [11]. It is likely that brown adipose tissue wet weight is a more variable and less satisfactory index of thermogenic capacity than various biochemical measures (e.g., GDP binding).

We noted a consistent effect of exercise on testis weights. That is, active, vehicle-treated hamsters exhibited a modest, but significant and replicable (Bartness and Wade, unpublished data) reduction in testis weight relative to the sedentary controls. In melatonin-treated hamsters, exercise did not further reduce the already low testis weights. We are unsure as to the importance of this finding, but exercise appears to affect testis weight under other experimental conditions. For example, the rate of testis regression is reduced in exercising Syrian hamsters exposed to short photoperiods compared to sedentary controls (Jeffrey Elliott, personal communication, 1984).

Because the behavioral ecology of Syrian hamsters is virtually unknown and only scant data exists for Siberian hamsters, one can only wildly speculate as to the adaptive significance of the tight coupling of energy intake with energy output observed in Siberian but seen infrequently in Syrian hamsters. Syrian hamsters seem to be more flexible in their behavioral response to energy demands than Siberian hamsters in that they can store energy externally, through food hoards [10,30], and internally, through the accretion of the white adipose tissue in response to diet [31–33] and photoperiod [1, 32, 35]. In contrast, Siberian hamsters do not enjoy this metabolic flexibility in response to increased energy demands. To our knowledge there are no reports of hoarding in Siberian hamsters. Furthermore, they do not increase their carcass lipid when fed a high-fat diet as do Syrian hamsters [1, 2, 31–33, 35], rats (e.g., [17, 21, 26]) and mice (e.g., [6,17]). In addition, Siberian hamsters decrease their body weight as carcass lipid in response to short days (i.e., winter-like photoperiod) [34], an opposite response to that of Syrian hamsters [1, 32, 35]. Following periods of starvation, Syrian hamsters, unlike rats (e.g., [19]), do not exhibit a post-fast hyperphagia [22,27]. However, Siberian hamsters increase their food intake roughly proportional to the length of the starvation period (Bartness, Levine and Morley, unpublished observations). Finally, Siberian hamsters show daily torpor in response to short photoperiods or short photoperiods combined with cold exposure [13,29]. Syrian hamsters only rarely hibernate under these conditions (Bruce Goldman, personal communication). Therefore, it appears that Siberian hamsters respond to increased energy demands more readily than do Syrian hamsters, perhaps because of a reduced ability to store energy either internally or externally.

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