Somatic, endocrine, and serum lipid changes during detraining in adult hamsters¹,²

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ABSTRACT Effects of abrupt discontinuation of chronic exercise on body composition and serum lipid, insulin, and glucagon concentrations were examined in adult female hamsters. Thirty-six hamsters (100 to 120 g) were randomly allotted to two groups of 18 each for an 84-day study. One group served as controls and were sedentary throughout the experimental period; another group had access to voluntary running on horizontal discs during the first 42 days of the experimental period. Six hamsters from each group were killed at the end of the exercise period and at 12 and 42 days after retirement. Results showed that hamsters engaged in high levels of voluntary activity increased food intake by about 10 to 20% and this effect persisted for about 10 days after retirement. Voluntary running resulted in a 60% reduction in body fat content and a 30% decrease in serum triglyceride levels. Exercise was also associated with an increase in body cholesterol level, a decrease in glucagon concentration, and a suggestive increase in serum insulin level. Increased food consumption and changes in serum insulin and glucagon may reflect compensatory adjustments to increased energy expenditure of exercise. Discontinuation of exercise resulted in a reversal of exercise effects on body fat, body cholesterol, and serum triglyceride levels. Am. J. Clin. Nutr. 34: 373-376, 1981.

KEY WORDS Hamsters, exercise, detraining, body composition, serum triglycerides, serum cholesterol

Introduction

Health effects of physical exercise in humans have been the subject of intensive investigation in recent years. It is often claimed by the public and by professionals alike that routine physical exercise can promote physical fitness, reduce development of atherosclerosis, and decrease risk of coronary heart disease (1, 2). In recent years, routine, chronic exercise has become an increasingly popular practice to many individuals in our society. However, many who undergo regular exercise fail to maintain high levels of activities. Abrupt cessation of chronic physical exercise has been noted by many to be associated with increase in body weight and often also body fat (3). Nevertheless, detailed studies to show the impact of detraining in humans or experimental animals are still rare. In experimental animals such as rats, discontinuation of chronic running has been shown to be associated with reversal of endocrine (4) and metabolic (5) changes seen during exercise. In the present study, using the hamster as an animal model and voluntary disc-running as a way of physical exercise, we attempted to determine the effect of discontinuation of exercise on serum lipid levels and body fat content, and two hormones, insulin and glucagon, which principally control the synthesis and mobilization of body fat.

Materials and methods

Thirty-six female hamsters (Charles River Lakeview hamsters, Charles River Breeding Laboratories, Inc., Wilmington, MA) (Mesocricetus auratus, Waterhouse) weighing 100 to 120 g each and about 10 wk old were randomly allotted to two groups of 18 each. One group served as sedentary controls throughout the 84-day experimental period. The other group, experimental, had access to horizontal discs for voluntary running during the first 42 days and were removed from the activity cages (retired) during the remaining 42 days. Exercising hamsters were housed individually in acrylic boxes (30

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the amount of food consumed by exercise hamsters in excess of the amount consumed by sedentary hamsters. Starch. The amount of starch added was in proportion to the amount of food consumed by exercise hamsters in excess of the amount consumed by sedentary hamsters. For example, if hamsters in the exercise group consumed 110% of the amount of food consumed by the controls their diet will be 100 g of the stock diet diluted with 10 g starch. The level of supplementation with starch was adjusted twice weekly. Thus, hamsters in both groups, consumed diets that were essentially nonnitrogenous. Amounts of food consumed and body weight gains were monitored throughout the experimental period.

To determine the biochemical effects, six hamsters from each group were killed by decapitation on the last day of the exercise period and on the 12th day and the 42nd day after the termination of exercise. They were all killed between 1:00 and 3:00 PM and after 6 h of deprivation of food, but not water. Blood samples collected from the neck at the time of killing were kept in cold (icy) water, and centrifuged within 2 h to separate serum. Serum was analyzed for total cholesterol (6), triglyceride (7), insulin, and glucagon (8). Carcasses without gastrointestinal contents were analyzed for body water and fat content. Each carcass was autoclaved, homogenized and freeze-dried to determine water content. The dried samples were then analyzed for total fat and total cholesterol as described previously (9).

Results were statistically analyzed by Student's t test (10).

Results

During the exercise period each hamster ran an average of 27,700 ± 7500 revolutions per day. Based on the running path of approximately 15 to 20 cm in diameter, the total running distance would be approximately 13 to 17 KM/day. The level of activity decreased slightly with aging. Food consumption (g/100 g/day) and body weight changes throughout the experimental period are shown in Figures 1 and 2, respectively. Voluntary running resulted in a 10 to 20% increase in food consumption over the sedentary controls and this increase persisted for a period of approximately 10 days after retirement. Weight increments between the two groups were not different during the exercise period. However, the lead by experimental group reached a significant level (p < 0.05) within 2 wk after voluntary running was discontinued. The retired hamster maintained the lead in body weight (p < 0.05) during the remaining of the experimental period.

Somatic and endocrine changes associated with discontinuation of running are presented in Table 1. Disc-running significantly reduced body fat content of hamsters to approximately 40% of the controls. Upon termination of running activity, there was a rapid increase in body fat which doubled within a period of 12 days. At 42 days after retirement, body fat of the experimental group was only slightly lower than that of the sedentary controls. Body fat increased with age in the sedentary hamsters. Body water content showed an inverse relationship with that of body fat and the body fat increase in the experimental group nearly compensated for the decrease in body water. Body cholesterol content showed an inverse relationship with that of total body fat. At the end of the exercise period the exercised hamsters had significantly higher levels of body cholesterol than controls. Upon discontinuation of running, body cholesterol decreased to control levels.

Serum glucose and serum triglyceride concentrations were both significantly decreased by disc-running but such effects disappeared gradually after discontinuation of exercise. At 12 days after discontinuation, neither of these two effects were significantly different from the controls although both were slightly lower. Serum cholesterol level was not altered by exercise or discontinuation of exercise. Serum insulin concentration appeared to be elevated in exercising hamsters both during exercise and following discontinuation, but none of the values was significantly different from the controls. Serum glucagon concentration was reduced by voluntary running. This effect did not persist after running was terminated.

Discussion

Effects of exercise and its discontinuation on somatic and physiological factors under...
FIG. 1. Average daily food intake (g/hamster/day). Values were based on total number of hamster available at each time point: 18 hamsters for 0 to 42nd day, 12 hamsters for 43rd to 54th day and six hamsters for the remaining period.

FIG. 2. Body weight gain of hamsters. See Figure 1 for explanations.

TABLE 1
Effect of exercise and discontinuation of exercise on body weight gain, serum lipid levels, and body composition in hamsters

<table>
<thead>
<tr>
<th>Days after retirement</th>
<th>Sedentary</th>
<th>Exercise</th>
<th>Sedentary</th>
<th>Exercise</th>
<th>Sedentary</th>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>106 ± 8†</td>
<td>108 ± 11</td>
<td>110 ± 7</td>
<td>105 ± 4</td>
<td>103 ± 5</td>
<td>106 ± 6</td>
</tr>
<tr>
<td>Total body wt gain (g)</td>
<td>36 ± 10</td>
<td>32 ± 8</td>
<td>37 ± 7</td>
<td>51 ± 9*</td>
<td>58 ± 26</td>
<td>64 ± 14</td>
</tr>
<tr>
<td>Serum cholesterol (mg/dl)</td>
<td>221 ± 10</td>
<td>198 ± 20</td>
<td>217 ± 28</td>
<td>230 ± 28</td>
<td>230 ± 33</td>
<td>217 ± 14</td>
</tr>
<tr>
<td>Serum triglycerides (mg/dl)</td>
<td>287 ± 45</td>
<td>205 ± 29*</td>
<td>236 ± 56</td>
<td>198 ± 46</td>
<td>228 ± 77</td>
<td>196 ± 19</td>
</tr>
<tr>
<td>Serum glucose (mg/dl)</td>
<td>98 ± 7</td>
<td>88 ± 4*</td>
<td>102 ± 9</td>
<td>95 ± 4</td>
<td>111 ± 10</td>
<td>111 ± 10</td>
</tr>
<tr>
<td>Serum insulin (uU/ml)</td>
<td>25 ± 22</td>
<td>51 ± 38</td>
<td>69 ± 45</td>
<td>104 ± 77</td>
<td>66 ± 33</td>
<td>101 ± 73</td>
</tr>
<tr>
<td>Serum glucagon (pg/ml)</td>
<td>316 ± 70</td>
<td>232 ± 57*</td>
<td>227 ± 65</td>
<td>311 ± 114</td>
<td>288 ± 98</td>
<td>267 ± 61</td>
</tr>
<tr>
<td>Carcass moisture (%)</td>
<td>58.0 ± 2</td>
<td>65.7 ± 2.5***</td>
<td>55.9 ± 3</td>
<td>61.8 ± 1.9**</td>
<td>55.6 ± 2.5</td>
<td>59.3 ± 2.3</td>
</tr>
<tr>
<td>Carcass fat (%)</td>
<td>18.5 ± 3</td>
<td>7.6 ± 3***</td>
<td>21.4 ± 5</td>
<td>14.9 ± 2.9</td>
<td>23.3 ± 6.6</td>
<td>19.3 ± 35</td>
</tr>
<tr>
<td>Lean body mass (%)</td>
<td>23.5 ± 2.8</td>
<td>26.7 ± 3.4</td>
<td>22.7 ± 3.1</td>
<td>23.3 ± 2.9</td>
<td>21.1 ± 2.6</td>
<td>21.4 ± 2.4</td>
</tr>
<tr>
<td>Carcass cholesterol (mg/g)</td>
<td>1.32 ± 0.2</td>
<td>1.64 ± 0.1*</td>
<td>1.14 ± 0.1</td>
<td>1.35 ± 0.1*</td>
<td>1.23 ± 0.3</td>
<td>1.22 ± 0.1</td>
</tr>
</tbody>
</table>

† Mean ± SD for six hamsters.
Statistically different from the sedentary group on basis of Student's t test. * p < 0.05; ** p < 0.001; *** p < 0.01.
‡ Calculated by differences (100% - % body fat - % body water).
various conditions are not yet clearly understood. Brief, intense exercise promotes mobilization of metabolic fuels and suppresses appetite in animals (1) and man (2). Prolonged, moderately intense exercise or physical activities are associated with increases in food consumption commensurate with energy expenditure in both animals (3) and man (4). Prolonged, moderately intense exercise is also associated with metabolic adjustments to enhanced energy expenditure and energy conservation and storage.

In the present study, hamsters exposed to disc running increased food consumption by 10 to 20% over the sedentary controls. This effect persisted for approximately 10 days after discontinuation of running. The delay in adaptation to reduced energy expenditure probably is the major factor that contributes to the rapid rate of body fat accumulation during the early phase of retirement.

The present study showed that the effect of voluntary disc-running on serum lipids and body composition in hamsters is relatively similar to exercise effects observed in humans. Physical exercise reduced serum triglyceride level and body fat content while having little or no effect on serum cholesterol levels (1). Further, in hamsters, discontinuation of chronic exercise resulted in a rapid regaining of body weight and body fat similar to that observed in humans (5, 11). The decrease in body fat seemed to be almost entirely compensated by an increase in body water. Lean body mass was not significantly changed in exercise or discontinuation of exercise.

Because of the similarities in the response of serum lipid levels and body composition to chronic exercise and discontinuation of exercise between the human and the hamster, it is probable that the hamster could be a useful model for studying exercise and detraining effects in humans. Hamsters seem to be a rather athletic species in that nearly all will run on the disc voluntarily. The activity level achieved clearly shows the exercise effects evidenced by reduced serum triglyceride concentration and total body fat content. Hamsters also respond to increased energy demand of exercise by increasing its food consumption (Reference 12 and the present study).

It is probably that increases in serum insulin concentration during exercise and retirement periods suggested by this experiment and more clearly in a previous one (13), and decreases in serum glucagon level may reflect the operation of a physiological mechanism favoring energy conservation that has been stimulated by fat loss and by the energy demands of high levels of voluntary activity. In hamsters, voluntary activity also increased serum growth hormone concentration during exercise and early retirement periods (13). This increase probably contributed significantly to somatic growth during these periods.

References