Effects of Treadmill Training and/or Diet Treatment on Obesity Induced in the Rat by High-fat Diet.

Yi SYUU

Abstract
Diet induced obesity (DIO) was produced in 1-month-old male Sprague-Dawley rats during a 10-week period who were fed a high-fat (20%), high-calorie (7.6 kcal/g) DIO diet. Effects of three weight-reducing methods (treadmill training, low-fat diet, treadmill training plus low-fat diet) on body weight, body fat rate, feed efficiency, total cholesterol and triglyceride, plasma insulin and insulin receptor binding capacity on the hepatic cell membrane in the obese rats were investigated. The results indicated that feed efficiency increased, the insulin receptor binding capacity on the hepatic cell membrane decreased and hyperinsulinemia developed in the obese rats. A low-fat diet did not affect body fat rate, feed efficiency, insulin receptor binding capacity on the hepatic cell membrane or hyperinsulinemia. With unrestricted food intake, treadmill training in DIO rats depressed hyperinsulinemia significantly and reduced body fat. Furthermore, treadmill training plus low-fat diet was most effective in inhibiting the body weight gain in the obese rats; it also reduced body fat and feed efficiency to the non-obese control levels. The results indicate that DIO is related to the increase in feed efficiency, the decrease in insulin receptor binding capacity on the hepatic cell membrane and hyperinsulinemia.

Key words: diet induced obesity; feed efficiency; hyperinsulinemia; insulin receptor binding; treadmill training

INTRODUCTION

In modern athletics, athletes try their best to reduce body fat and increase muscle content in order to maintain high performance. High body fat rate may result in many diseases blood vessel diseases, diabetes mellitus and some neoplasm etc. The widely used weight reducing methods are food restriction, exercise and medicine. Although some medicine can reduce weight significantly, they may have some side effects, and, therefore, may not be suitable for long-term use. Thus, safer and more credible methods are food restriction and exercise.

To investigate weight-reducing methods, we must understand the mechanisms of obesity genesis. Previous studies have shown that 33-week food restriction in genetically obese Zucker rats reduced the body weight but did not change the body fat, whereas treadmill training could reduce both the body weight and the body fat. Other studies show that incretion disharmony is usually accompanied by hyperinsulinemia and decrease in insulin receptor binding capacity in both obese animals and obese humans. However, the effects of different weight-reducing methods on the incretion are not clear. This study was designed to determine the effects of treadmill training and/or diet treatment on obesity induced in the rat by high-fat diet.
METHODS

1. Animals and diet.

One-month-old male Sprague-Dawley rats were admitted at least 1 week before use and kept on a 12-hour light-dark cycle at 23-24 °C. The rats were randomized by weight and fed either powdered Purina rat chow (4.0 Kcal/g) or a powdered semisynthetic diet composed of 47% rat chow, 8% corn oil, and 47% sweetened condensed milk that contained (by weight) 7.6 Kcal/g, 20% fat, 55% carbohydrate, and 16% protein [DIO diet]. Caloric contents of the two diets were determined by bomb calorimetry. 100 SD rats were divided randomly into two groups: DIO diet group (N = 80) and control group (N = 20). After 10 weeks, 36 obese rats chosen by their body weight were divided randomly into the following four groups: obese group (N = 12, DIO), training group (N = 8, DIO-T), low-fat-diet group (N = 8, LD) and training combined with low fat diet group (N = 8, LT). The DIO group was fed with DIO diet continually, the LD group was fed with low-fat-diet (4.0 kcal/g), DIO-T group was fed with DIO diet (7.6 kcal/g) over treadmill training, and the LT group was fed with the same low-fat-diet over treadmill training. After 10 more weeks, the rats were tested for total cholesterol, triglyceride, glucose, plasma insulin and insulin receptor binding capacity on the hepatic cell membrane determination.

2. Treadmill Training Arrangement

We arranged the running treadmill speed at 20 m/min and the slope at 5 degree (equal to 65-75% V02max) according to the previous study. The beginning speed of the running table training was 15 m/min for 30 minutes. After one week we increased the speed to 20 m/min and made the rats run for 60 minutes.

3. Plasma constituents

Plasma insulin was determined by radioimmunoassay using the back titration method of Wright et al. and pure rat insulin standard. Triglycerides and glucose were determined using the methods of Sampeon et al. as adopted for the Technicon Auto-Analyzer.

Statistics

Feed efficiency was calculated by dividing the average weight gain (in g-rat⁻¹·day⁻¹) by the average food intake (in kcal (rat⁻¹·day⁻¹)) for each individual rat over a given 1-week period.

Data were analyzed using one-way analysis of variance, followed by simple effect tests and comparisons of individual means. F or t values for any effects reported as significant in this study exceeded probability levels of 0.05.

RESULTS

1. Body weight and body fat rate

Figure 1 shows that DIO, LD, DIO-T and LT groups weighed significantly more than control group from 8th week (P < 0.05). With unrestricted food intake, treadmill training (DIO-T) or changing DIO diet to low fat diet (LD) did not significantly influence body weight. However, treadmill training plus low-fat diet (LT) decreased the body weight to control level (Table 1). Body fat rate in DIO and LD group was significantly higher than control group (P < 0.05). DIO-T and LT decreased the body fat rate similar to control level (Table 1).

2. Feed efficiency

Figure 2 shows that in the first 10-week, feed efficiency in DIO, LD, DIO-T and LT groups was greater than that in control group (P < 0.05), but in the second 10-week there was no significant difference between control and LT.

<table>
<thead>
<tr>
<th>Table 1. Body Weight, Body Fat Rate</th>
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<td>Group</td>
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* : vs. Control, P<0.05; † : vs. DIO, P<0.05
groups. Feed efficiency in LT group was significantly lower than that in DIO group ($P < 0.05$).

3. Total cholesterol, triglyceride, glucose, plasma insulin and insulin receptor binding

Table 2 shows that total cholesterol, triglyceride and glucose in DIO, LD, DIO-T and LT groups have no significant difference compared with control group, indicating no appearance of hyperlipidemia.

Insulin in DIO and LD groups was significantly higher than that in control group ($P < 0.05$). There was no significant difference among control, DIO-T and LT groups. Both DIO-T and LT significantly reduced the increased insulin level compared with DIO group ($P < 0.05$). Insulin receptor binding capacity in DIO and LD groups was lower than that in control group ($P < 0.05$). The insulin receptor binding in DIO-T and LT groups was significantly higher than that in DIO group with no difference than the control group (Table 2), indicating treadmill training could improve insulin receptor binding capacity in DIO rats. However, only changing fat content in diet did not affect the binding capacity.

**DISCUSSION**

This study investigated the effects of exercise and exercise plus low fat diet on obesity induced in rats by high-fat diet. We successfully observed that with unrestricted food intake treadmill training plus low diet is the best way to reduce the body weight and body fat rate as well as improve the hyperinsulinemia in DIO rats.

In general, hypothalamus obese rats, genetically obese rats and diet-induced obese (DIO) rats are usually used to study obesity. Because the DIO rat model is under physiological condition and is easy to establish, we used the DIO model in the present study.

Although the syndrome of obesity in man remains unclear, it is becoming increasingly clear that several forms of obesity with potentially different etiologies exist, including the severe, early-onset hyperplastic hypertrophic

![Fig. 1 Body weight change in each group over 20 weeks](image1.png)

![Fig. 2 Feed efficiency in each group](image2.png)
form. Because the development of most forms of obesity is associated with hyperphagia, the most commonly promulgated treatment for both prevention and amelioration of the obese condition, regardless of its origin, has been the prevention of hyperphagia by caloric restriction. Furthermore, the close association of the severe hyperplastic-hypertrophic obes form of obesity with the early onset of the obesity has led to the suggestion that infants and children may become hypercellular and obese due to early overfeeding and that prevention of early hyperphagia may prevent the later development of obesity. It is becoming increasingly clear from experimental studies on obese rodents that caloric restriction, while decreasing body weight, does not always decrease body fat to the desired extent.

Since food restriction may do harm to normal growth in adolescents and cannot be easily accepted by many obese people, we did not provide a food restriction in the present study. Under normal conditions, energy intake keeps balance with energy consumption. Whenever the surplus of energy intake over energy consumption, obesity will occur. Obesity seems to be deeply related to hyperphagia. Our data show that body weight and body fat rate in obese rats were higher than those in control group, but energy intake was the same as in the control group. We therefore conclude that DIO was not caused by hyperphagia. These results are almost in accordance with Levin et al.10 These results indicate that reduction of energy consumption and improvement of energy utilization might play an important role in obesity genesis. We hypothesized that the abnormality of fat oxidation might occur in DIO rats and the imbalance in energy metabolism might result in obesity. The increased feed efficiency in obese rats could support our hypothesis.

Our data show that with unrestricted food intake, neither changing high-fat diet to low-fat diet (LD) nor treadmill training with high-fat diet (DIO-T) affects body weight, body fat rate or feed efficiency. However, treadmill training with low-fat diet (LT) could decrease body weight, body fat rate and feed efficiency significantly, with no significant difference in the control group. The previous study shows that treadmill training could limit the storage of lipid in fat cells despite no changes in the numbers of fat cell.10

We observed that insulin in DIO and LD groups was significantly higher than that in control group, indicating that hyperinsulinemia had occurred. Hyperinsulinemia is known to play an important role in obesity genesis. First, insulin combines to the insulin receptor on hepatic cell membrane, and then induces a series of biochemical reactions inside the cells, such as activating receptor tyrosine kinase and phosphorylation of the receptor itself as well as increasing ions transportation. Our data show that insulin in DIO-T group and LT group was lower than that in DIO group with no significant difference in the control group, indicating that treadmill training can help DIO rats to improve hyperinsulinemia. However, there was no significant difference in blood insulin level and insulin receptor binding between LD and DIO groups, indicating that a decrease in fat content in the diet has no significant effect on hyperinsulinemia in dietary obese rats.

As has been shown in other chronic exercise studies, there may be an improvement of tissue insulin sensitivity of normal lean rats with swim training. For instance, researchers have observed improvement of glucose tolerance,11 increases in insulin binding to cell receptors,10 and enhanced glucose uptake by peripheral tissues10 in trained normal rats. Insulin resistance is present in muscle and adipose tissues of Zucker rats.10 The most dramatic effect of our moderate treadmill training on the DIO rat was depression of hyperinsulinemia that may reflect improvement of insulin sensitivity.

Summary

1. DIO was not caused by hyperphagia, but caused by the increase in feed efficiency.
2. With unrestricted food intake, treadmill training plus low fat diet is the best way to reduce the body weight and the body fat rate.
3. Treadmill training can improve hyperinsulinemia in obese rats, by improving insulin sensitivity.

REFERENCES


低脂肪食およびトレッドミル訓練が食餌性肥満ラットのダイエットに及ぼす影響

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Abstract

我々は、低脂肪食およびトレッドミル訓練がヒトの肥満に類似した高脂肪飼料誘発肥満ラットの体脂肪率、摂食効率及びインスリン作用に及ぼす影響について研究した。高脂肪飼料誘発肥満ラットにおいて、摂食効率（体重増加量/摂取エネルギー）の上昇、高インスリン血症、肝細胞膜インスリン受容体结合能の低下が認められた。トレッドミル訓練および低脂肪食+トレッドミル訓練は肥満ラットの肝細胞膜インスリン受容体結合能を高め、高インスリン血症を抑制する働きがあった。とりわけ、低脂肪食+トレッドミル訓練は肥満ラットの体重増加を抑制し体脂肪率を減少させた。これらの変化が高脂肪飼料誘発肥満ラットにおいてダイエット効果を発揮していると考えられる。

キーワード：高脂肪食、摂食効率、高インスリン血症、インスリン受容体結合能、トレッドミル訓練