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Effects of Exhaustive Exercise on Metabolic Changes in Obese Patients

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This study was undertaken to elucidate the effects of short, exhaustive work on metabolic changes of obese subjects. 6 obese men (obesity index: 146.6 ± 18.4%) and 20 healthy men were subjected to the 100 g glucose tolerance test (O-GTT) and exhaustive treadmill running followed by oral glucose administration (all-out exercise GTT).

As a result of maximal exercise glucose tolerance increased in the normal subjects, but decreased in the obese subjects. Increased catecholamine caused by exhaustive work in obese patients suppresses insulin secretion, which probably reduces the carbohydrate metabolism and induces FFA and glycerol release.

From these results it is suggested that exhaustive exercise is not fit for the exercise treatment for obese patients.

Recently many kinds of transportation and machines have caused people to become less active, while nutritious foods increase fat storage in the body. Consequently frequency of obesity has increased until 1979[13].

Obesity is sometimes one of the main causes of adult diseases and most obese men have disorders in carbohydrate and lipid metabolism.[12)15)25)] Therefore obesity should be improved by restriction of food intake and increase in energy consumption.

It is well known that exercise is effective for obese men to improve their metabolic disorders and to reduce their body weight.[1-4)10)17-20)27)29)] However, previous data showed that obese men had tendency to be less active.[5)6)16)26)] It is accordingly suggested that obese men should recognize the necessity of physical exercise and make efforts to control their physical conditions. But it doesn't seem that every kind of exercise is appropriate for obese men.[29)] Hard exercise for short periods, for example, brings about splanchnic glucose production by catecholamine, glucagon and glucocorticoid, which grow worse the carbohydrate and lipid metabolism.[7)8)11)28)31)] However hardly any papers have been reported about effects of intense exercise on metabolism in obese patients. Consequently this study was undertaken to elucidate the effects of exhaustive exercise for short periods on metabolism of obese men.

Subjects and Method

Six obese men, 19 to 20 years old, and twenty healthy subjects, 18 to 22 years old, took part in this study. Modified Broca's obesity index of 6 obese subjects was 146.6 ± 18.4%.

The experimental protocol is shown in Fig. 1. A glucose tolerance test (O-GTT) was, at first, performed on all subjects in a resting state following over-night fast. Then after a week all obese subjects and 5 of 20 healthy subjects did all-out exercise on the treadmill to the point of

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exhaustion for between 5 to 10 minutes. This was followed by a second 100 g glucose tolerance test 30 minutes after the exercise (all-out exercise GTT)

Expired gas of the 6 obese men and 2 healthy subjects was collected in the Douglas bags while they exercised and O_2 and CO_2 concentrations in the gas were analized to calculate $\dot{V}O_2$ max.

As shown in Fig. 1 blood was drawn from antecubital veins while the subjects were at rest and after the maximal exercise.

Blood lactate, blood glucose, Free Fatty acids (FFA), glycerol and IRI (Immuno-reactive insulin) were measured enzymatically or immunologically.

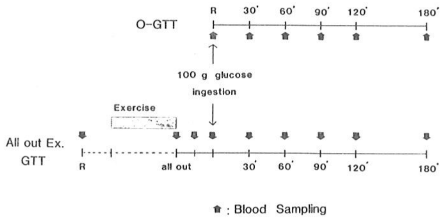

Fig. 1. Experimental protocol

Results

(1) $\dot{V}O_2$ max.

Table 1 indicates the results of $\dot{V}O_2$ max. in the obese and normal subjects. $\dot{V}O_2$ max. in the obese subjects was 3.5 ± 0.26 l/min. and $\dot{V}O_2$ max. per body weight was 37.2 ± 3.6 ml/kg/min. The normal subjects showed 3.28 and 2.86 l/min. of $\dot{V}O_2$ max. and 49.6 and 53.9 ml/kg/min. of $\dot{V}O_2$ max. per body weight, respectively. $\dot{V}O_2$ max. in both groups was almost the same, but $\dot{V}O_2$ max. per body weight in the obese men was far lower than that in the normal subjects.

Table 1. $\dot{V}O_2$ max. of the obese and healthy subjects.

Subject	$\dot{V}O_2$ max. (l/min.)	$\dot{V}O_2$ max./B.W. (ml/kg/min.)
Obese 1	3.76	43.2
2	3.40	33.6
3	3.65	38.8
4	3.16	33.4
5	3.28	37.2
6	3.78	37.4
	3.50 ± 0.26	37.2 ± 3.6
Normal 1	3.28	49.6
2	2.86	53.9

(2) Blood Lactate

Fig. 2 indicates the changes in lactate during O-GTT and all-out ex. GTT.

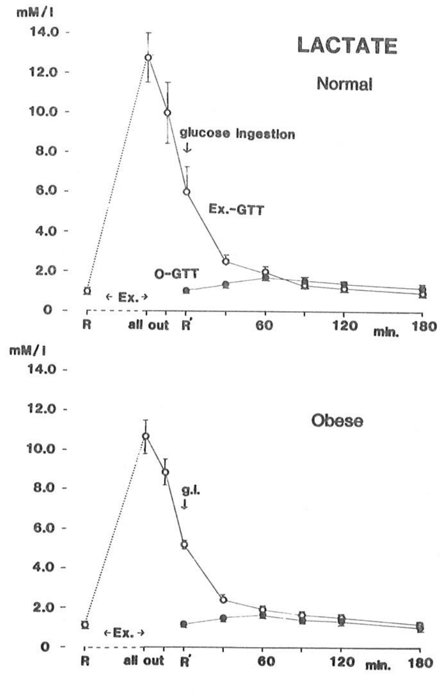

Fig. 2. Changes in blood lactate during O-GTT and all-out exercise GTT.

Blood lactate concentrations after oral administration of glucose increased a little after the ingestion. Both groups had almost the same tendencies. Lactate concentrations at rest during all-out ex. GTT were 1.0 ± 0.07 mM/l in the normal and 1.1 ± 0.20 mM/l in the obese men, then they increased after exhaustive exercise to 12.7 ± 1.42 mM/l, 10.6 ± 0.93 mM/l respectively. They decreased to the rest level 180 minutes after the ingestion.

The effects of glucose administration on the lactate concentrations could not be ascribed in either group in the all-out ex. GTT.

(3) Blood Glucose (Fig. 3)

Fasting blood glucose levels at rest were 94.1 ± 2.4 mg/dl in the normal and 90.5 ± 3.6 mg/dl in the obese subjects, and they showed peak values of 147.6 ± 4.8, 130.2 ± 5.7 mg/dl respectively 30 minutes after the ingestion of glucose.

During all-out ex. GTT blood glucose concentrations of both groups increased slightly after the exercise. The peak value after the ingestion of glucose was about 20 mg/dl lower in the normal subjects than that of O-GTT, while the concentration in the obese subjects was significantly higher than that of O-GTT ($p < 0.05$). These opposite results may be due to the decrease in the glucose tolerance in the obese men caused by the exhaustive exercise.

(4) Insulin (Fig. 4)

Insulin concentration showed a similar pattern to the blood glucose level. In normal subjects insulin concentration after oral glucose increased 8.1 ± 1.7 μU/ml at rest 66.5 ± 7.6 μU/ml 30 minutes after the glucose ingestion, while that in the obese subjects showed a far higher value; 20.6 ± 1.1 μU/ml at rest to 154.2 ± 17.7 μU/ml 30 minutes after the ingestion. The obese patients showed hyperinsulinamia during O-GTT.

After the maximal exercise insulin concentrations in the normal subjects increased to 88.6 ± 21.1 μU/ml which was higher than that during O-GTT. In the obese subjects insulin concentration after the exhaustive exercise, however, increased to

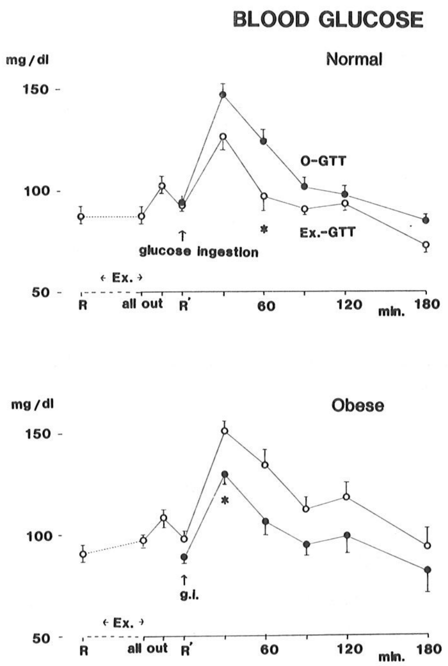

Fig. 3. Changes in blood glucose during O-GTT and all-out exercise GTT.
* $p < 0.05$

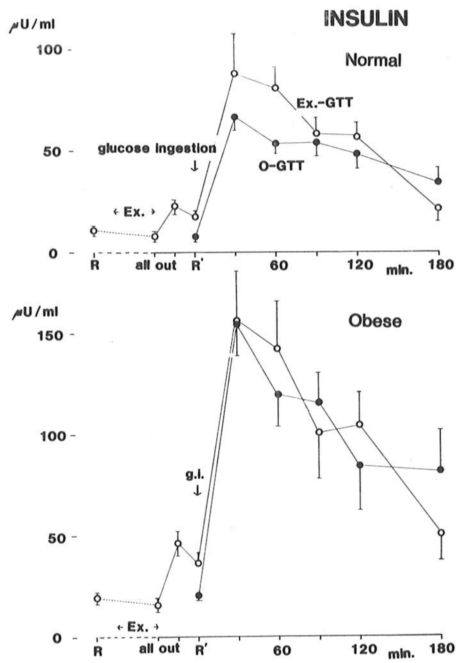

Fig. 4. Changes in serum insulin during O-GTT and all-out exercise GTT.

the same level as that during O-GTT. These results might have been due to the existance of insulin resistance.

(5) FFA (Fig. 5)

Free fatty acid concentrations decreased following oral glucose administration from 0.45 ± 0.04 mEq/l to 0.19 ± 0.01 mEq/l in the normal subjects, and from 0.52 ± 0.04 mEq/l to 0.20 ± 0.02 mEq/l in the obese subjects.

FFA decreased during exercise. After the exhaustive treadmill exercise FFA increased a little in the normal subjects, while FFA in the obese men showed 0.2 mEq/l increase 30 minutes after the exhaustion, and then decreased. As the consumption of FFA in muscles become reduced,

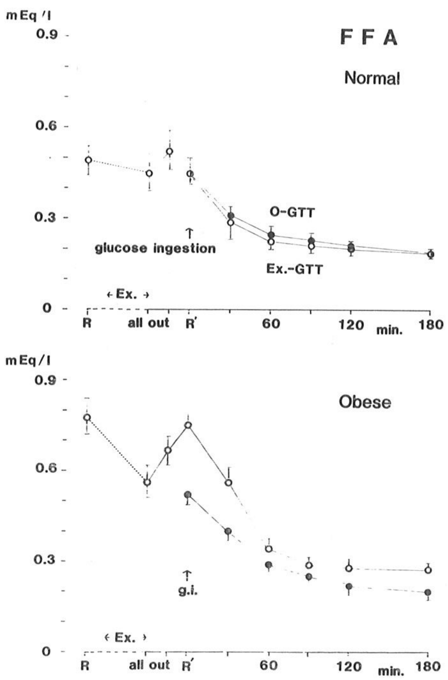

Fig. 5. Changes in free fatty acid during O-GTT and all-out exercise GTT.

FFA concentrations in the blood increased after the maximal exercise.

(6) Glycerol (Fig. 6)

Fasting glycerol concentrations were 0.131 ± 0.021 mM/l in the normal subjects and 0.152 ± 0.023 mM/l in the obese subjects, but they didn't show any significant changes after oral glucose administration in either group.

Glycerol concentrations increased during and after exhaustive exercises. The peak levels of each group were 0.24 ± 0.030 mM/l and 0.34 ± 0.021 mM/l for the normal and obese subjects respectively 15 minutes after the exhaustive exercise. Glycerol concentrations were suppressed by glucose administration during all-out ex. GTT.

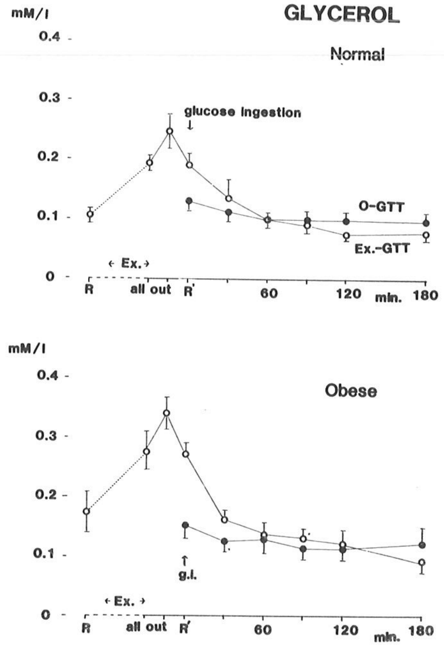

Fig. 6. Changes in glycerol during O-GTT and all-out exercise GTT.

Discussion

In order to reduce the body weight many kinds of exercise and dietary treatment are carried out by many obese subjects. The methods of exercise treatment done by them are walking, jogging, running, calithenics and so forth. Dietary treatment is available to control body weight by limiting the ingested energy, but severe restriction, suggested by Keys[14], Young[30], Oscai[18] and Ohta[17], brings about depression of the basal metabolic rate, lean body mass and body protein. Buskirk[4] also reported similar results. So it is recommended that obesity should be gradually reduced by mild dietary restriction and physical exercise which improves cardiovascular function and body composition[4)20)21)].

Gwinup[10] and Steven Lewis[27] reported on weight reduction of obese women by walking or jog-walking, and Pollock[21] did research on the improvement of cardiovascular function and body composition by walking. Oscai[19] reported in middle-aged men an average weight reduction of 4.5 kg as a result of 16-week running program. Björntorp[1] suggested that hyperinsulinamia was improved by physical training.

Intensive exercise is sometimes recommended to reduce body weight. However, even if the work in strenuous exercise for a short time were the same as that in mild exercise for a long time, metabolic changes would be different. There may be disadvantageous effects on obese men's metabolism in strenuous exercise.

The effects of short, exhaustive exercise on metabolism were determined in this study.

Blood glucose deceased during exercise as it was utilized as an energy source in the muscles. Immediately after the exhaustive exercise blood glucose concentration was reduced just slightly, though a lot of energy had been expended in treadmill running. This slight decrease seems to be caused by the compensation from splanchnic glucose out-put[31].

The peak level of blood glucose concentration during all-out ex. GTT was lower than that during O-GTT in the normal subjects, while the peak level in the obese subjects during all-out ex. GTT was significantly higher than that during O-GTT. Pruett[23] reported an increase in tolerance to glucose in healthy subjects after exhausting work, while glucose tolerance in the obese subjects in this study was reduced by exhaustive exercise which can become a stressor and induce catecholamine secretion[28]. Glucose tolerance in the normal subjects was increased after the exhaustive exercise in this study, too.

The patterns of change in insulin levels were also different between the normal and obese subjects. Insulin levels after the oral glucose administration during all-out ex. GTT were higher than those during O-GTT in the normal subjects, while insulin levels during all-out ex. GTT were almost the same as those of O-GTT in the obese subjects. The latter phenomenon can be explained in part catecholamine secretion or some other factors which suppressed insulin secretion[7)8)].

Free fatty acids decreased during exercise, but increased after the exercise, as reported by Pruett[22] and Rodahl[24]. The increase was larger and longer in the obese subject than in the normal subjects. The higher basal values and greater fat volume in the obese subjects probably caused those increases. Pruett[22] also suggested the magnitude and duration of the FFA increase after the exhaustive work was dependent upon the subject's energy expenditure during exercise which means the intensity of work load as related to the subject's $\dot{V}O_2$ max., the obese subjects, who had higher FFA concentrations than the normal men, showed larger values of $\dot{V}O_2$ max. Gray[9] reported that noradrenaline secretion was increased in exhaustive exercise, and returns to normal levels 15 to 30 minutes after the exercise. In this study FFA increases after the exercise were attributed to the suppression of utilization by muscles and continuing lipolysis by catecholamine[22].

Glycerol concentrations were increased after the maximal exercise. This also indicates continuous lipolysis in the adipose tissues after the exercise. Lipolysis is promoted by catecholamine and inhibited by glucose ingestion[22]. Tsutsumi[29] reported that exercise at the intensity of 120 heart beats/min. was appropriate for the exercise treatment for obese patients, because the mobilization of FFA is more marked at this intensity than at severer or milder one.

According to the present study glucose tolerance increased in the normal subjects after the exhaustive exercise, but decreased in the obese subjects, which is mainly ascribed to the low level of activity in the obese men. The exhaustive work, which brings about catecholamine secretion, results in more severe stress in the obese men. Catecholamine promotes the mobilization of FFA, but also suppresses insulin secretion, therefore glucose tolerance decreases.

These results might show that exhaustive work is not so appropriate for the purpose of weight reduction of obese men.

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