A Rice Diet Is Associated with Less Fat Synthesis/Accumulation than a Bread Diet before Exercise Therapy

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Summary For effective exercise therapy after waking up, we focused on the staple food in diet therapy, and compared rice and bread diets. The subjects were 10 healthy college male students. After fasting for 12 h or more from the previous day, the subjects had breakfast consisting of rice (protein, 6.3 g; fat, 0.9 g; CHO, 79.3 g; energy, 368 kcal) or bread (protein, 15.7 g; fat, 5.8 g; CHO, 79.2 g; and energy, 450 kcal) containing the same amount of carbohydrates and the same side dishes (protein, 7.0 g; fat, 9.5 g; CHO, 21.3 g; energy, 199 kcal) in the morning 30 min before the initiation of exercise on a bicycle ergometer at an intensity of about 50% VO2max for 60 min. Measurements of the heart rate and expired gas were initiated 15 min before the start of exercise and continued until 10 min after exercise. Blood was collected before the meal, immediately before and 15, 30, and 45 min after the initiation of exercise, and immediately, 15, and 30 min after its termination. After breakfast containing carbohydrates, decreases were observed in the levels of free fatty acid and noradrenalin. Blood insulin (meal×time, p<0.05 ANOVA) and triglyceride (meal×time, p<0.01, ANOVA) changed at higher levels in the bread diet than in the rice diet. Blood triglyceride is a resource of fat synthesis/accumulation, and insulin promotes its action. Therefore, the bread diet may promote fat synthesis/accumulation compared with the rice diet.

Key Words exercise therapy, breakfast, glucose metabolism, fat metabolism, catecholamine

Exercise therapy and dietary therapy are indispensable for the prevention and treatment of lifestyle-related diseases such as ischemic heart disease and diabetes mellitus. However, there have been only a few studies on the influences of dietary therapy on exercise therapy. The principles of dietary therapy for life-style related disease are restrictions of salt and energy intakes. Excessive carbohydrate restriction causes gluconeogenesis, inducing a decrease in the skeletal muscle that plays a primary role in glucose metabolism and fat metabolism. Therefore, exercise/dietary therapy while maintaining carbohydrate intake is desirable.

In addition, prolonged fasting after a meal promotes fat metabolism, and the degradation of triglyceride (TG) accumulated in fat cells during exercise (1). However, release of a large amount of free fatty acid (FFA) due to TG degradation sometimes causes severe ventricular extrasystoles in patients with ischemic heart disease (2). In addition, fasting enhances sympathetic activity, increasing the risk of sudden death. Therefore, for safe and effective exercise therapy after waking up, it should be performed after breakfast containing carbohydrates.

In this study, considering exercise therapy after breakfast, we evaluated the influences of carbohydrates from rice and bread as the staple on glucose metabolism, fat metabolism, and the catecholamine level during exercise.

METHODS

Subjects. Ten healthy college male students took part in this study (Table 1). All subjects were fully

Table 1. Age and physical characteristics of subjects.

| Subject | Age (y) | Height (cm) | Weight (kg) | BMI (kg/m²) |
|---------|---------|-------------|-------------|-------------|
| YS      | 22      | 173         | 59          | 19.7        |
| DI      | 23      | 169         | 58          | 20.3        |
| TS      | 23      | 168         | 52          | 18.4        |
| TK      | 20      | 171         | 65          | 22.2        |
| KU      | 21      | 177         | 64          | 20.4        |
| SF      | 27      | 165         | 56          | 20.6        |
| ST      | 20      | 170         | 64          | 22.1        |
| KY      | 20      | 170         | 60          | 20.8        |
| KT      | 22      | 170         | 57          | 19.7        |
| HI      | 21      | 175         | 61.5        | 20.1        |

| Mean    | 21.9    | 170.8      | 59.7        | 20.4        |
| SD      | 2.1     | 3.5         | 4.1         | 1.1         |

BMI: body mass index (weight (kg)/height (m²)).
Table 2. Nutrient composition of experimental diet (dry matter basis).

|                | Weight (g) | Energy (kcal) | Protein (g) | Fat (g) | Carbohydrate (g) |
|----------------|------------|---------------|-------------|---------|------------------|
| Rice (Japonica) | 104        | 368           | 6.3         | 0.9     | 79.3             |
| White wheat bread | 180       | 450           | 15.7        | 5.8     | 79.2             |
| Curry           | 220        | 199           | 7.0         | 9.5     | 21.3             |

Fig. 1. Mean (±SD) values for oxygen expenditure (A) and respiratory quotient (B) over time during rice (open symbols) and bread (closed symbols) trials.

Exercise was performed using a bicycle ergometer (CORIVAL 400, Lode, The Netherlands) at an intensity of about 50% VO2max that had been determined by an exercise test for 60 min. Measurements of the heart rate and expired gas were initiated 15 min before the start of exercise and continued until 10 min after its termination. Blood was collected before the meal, immediately before and 15, 30, and 45 min after the initiation of exercise, and immediately, 15 and 30 min after its termination.

Measurements. The heart rate, oxygen expenditure, and respiratory quotient were measured using an AMIS 1000SM (Innovision Denmark). The mean value during a 15-min rest before the initiation of exercise, and mean values at 5-min intervals during and after exercise were obtained as data for analysis. Based on oxygen expenditure and respiratory quotient, energy expenditure and estimated carbohydrate oxidation and fat oxidation were also calculated.

Blood was collected using a cannula placed in an antibrachial vein. Plasma glucose, serum insulin,
serum TG, and serum FFA were measured in all blood samples, and plasma adrenalin and noradrenalin were measured in blood samples obtained before the meal, immediately before and 30 min after the initiation of exercise, and immediately and 30 min after the termination of exercise. Since blood sampling showed hemolysis in 1 subject, the blood measurement items were evaluated in the other 9 subjects.

Statistical analyses. All results were expressed as the mean±SD. The rice and bread diet trials were compared by repeated measure ANOVA. When interaction was observed, the paired t-test was performed at the same measurement point. In addition, values in the blood measurement items were compared with those before the meal in each trial by Dunnett’s test. In all analyses, p<0.05 was regarded as significant.

RESULTS

1) Heart rate, oxygen uptake, respiratory quotient
The heart rate during exercise in the subjects was 118±11 beats/min. No significant difference was observed in oxygen expenditure or respiratory quotient between the two diet trials (Fig. 1). The respiratory quotient during exercise was about 0.80–0.87, suggesting that carbohydrates and fat used as energy sources during exercise accounted for about 50% each.

2) Energy consumption and estimated carbohydrate oxidation and fat oxidation
The energy consumption and estimated carbohydrate oxidation and fat oxidation calculated from oxygen expenditure and respiratory quotient are shown in Fig. 2. No significant difference was observed in any item between the two trials.

3) Plasma glucose, serum insulin, serum TG, and serum FFA
Figure 3 shows changes in plasma glucose and serum insulin. Plasma glucose significantly increased after the meal but decreased after the initiation of exercise in both trials. In the bread diet trial, plasma glucose did not exceed the level before the meal until the termination of exercise. In the rice diet trial, the plasma glucose level 45 min after the initiation of exercise was significantly higher than that before the meal. The plasma glucose level after the termination of exercise was sig-
The TG level showed a meal-time interaction, being significantly higher in the bread diet trial than in the rice diet trial immediately after exercise or later. Evaluation of changes in each trial showed a value higher than that before the meal from 30 min after the initiation of exercise until immediately after exercise in the rice trial but from immediately before the initiation of exercise until 30 min after exercise in the bread diet trial. FFA decreased after the meal and increased after the initiation of exercise in both trials. However, no significant difference was observed between the two trials, and neither trial showed values higher than the value before the meal during or after exercise (Fig. 4).

4) Plasma adrenalin and noradrenalin

Figure 5 shows changes in adrenalin and noradrenalin. Only the adrenalin level immediately after exercise was higher than the value before the meal in both trials. The noradrenalin level decreased after the meal in both trials but was higher than that before the meal 30 min after the initiation of exercise and immediately after exercise in the bread diet trial and only immediately after exercise in the rice diet trial. In both trials, the noradrenalin level rapidly decreased after exercise and was lower than that before the meal 30 min after exercise. No interaction was observed for adrenalin or noradrenalin in either trials.

DISCUSSION

One purpose of this study was to enhance the safety of exercise therapy after waking up, upon which TG degradation in fat cells becomes active due to overnight fasting, and a large amount of FFA is released into the blood. Aerobic exercise during fasting further enhances TG degradation, but FFA is toxic and FFA at a concentration of 2 mEq/L or more increases the risk of arrhythmia and even sudden death (3-5). Excessive secretion of catecholamines such as adrenalin and noradrenalin directly stimulates the myocardium, sometimes inducing acute cardiac failure or arrhythmia (6). Since both fasting and exercise promote catecholamine secretion, exercise during fasting causes excessive catecholamine secretion in addition to release.
of a large amount of FFA, which may result in potentiation. In this study, FFA decreased after the meal, and increased after exercise only to the level before the meal (The highest level was 0.98±0.58 mEq/L observed in the bread diet trial after the initiation of exercise). In addition, noradrenalin decreased after the meal. Therefore, when exercise therapy is performed in patients with ischemic heart disease and those with hypertension or diabetes mellitus as coronary risk factors, exercise after breakfast may be safer. However, this benefit did not differ between the rice and bread diets.

Another purpose of this study was to increase the effects of exercise therapy by diet selection. Our results showed no significant differences in energy consumption and estimated oxidation of carbohydrates or fat between the rice and bread diets. However, the serum TG and insulin levels changed at a lower level in the rice diet than in the bread diet trial than in the bread diet trial. Serum TG is degraded by lipoprotein lipase (LPL) and incorporated into cells. Since insulin enhances the LPL activity of adipose tissue (7), the changes in TG at a high level appear to be contradictory to those in FFA at a high level in the bread diet trial. However, nutritional composition shows a higher amount of fat in bread than in rice. Therefore, the difference in TG observed in this study may be the influences of the difference in fat in the nutritional composition between rice and bread.

As described above, in adipose tissue, insulin promotes the transport of circulating lipids to fat cells by inducing LPL; thus, insulin promotes fat synthesis/accumulation. Even after intake of the same weight of carbohydrates, the responses of plasma glucose and insulin differ among carbohydrate food materials. Therefore, as an objective parameter for changes in plasma glucose, the glycemic index is widely used (8). Foods with a high glycemic index have marked fat synthesis/accumulation actions. The glycemic index was reported to be lower in Japanese rice than in bread (bread:rice=100:68) (8). This study also showed changes in insulin at a lower level in the rice diet than in the bread diet, supporting the difference in the glycemic index between the two diets. The primary regulatory molecule for insulin secretion is glucose. Some amino acids (represented by arginine) as protein degradation products also stimulate insulin secretion in association with glucose (7). The higher amount of protein in the nutrient composition in the bread diet than in the rice diet may be also associated with the increase in insulin.

The differences between the rice and bread diets...
observed in this study were changes in both serum TG and insulin at a higher level in the bread diet than in the rice diet. According to the standard tables of food composition in Japan, bread often taken as a staple shows higher fat and protein levels than rice when the amount of carbohydrates is the same (9), and a generally higher glycemic index than rice (8). This indicates that the bread diet is associated with a higher level of TG involved in fat synthesis/accumulation and a higher level of insulin promoting these actions in the blood. Therefore, since exercise therapy aims at fat utilization, the bread diet promotes fat synthesis/accumulation compared with the rice diet. Specialists with nutritional knowledge may be able to adjust side dishes according to differences in the nutrient composition of the staple, but it is difficult for patients and their families. Therefore, as a meal that increases the effects of exercise therapy, rice would be more beneficial than bread.

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