Effects of Red-Pepper Diet on the Energy Metabolism in Men

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Summary We investigated the effects of dietary red pepper on the energy metabolism in male subjects. In the first experiment, after having a standardized dinner on the previous evening, the subjects consumed a breakfast (650kcal) either with or without 10g of red pepper. For 150 min after the meal, they took a rest and their expired gas was collected. During the initial 30 min after the meal, the energy expenditure tended to be higher in the red-pepper diet period than in the control diet period. For the remaining 120 min, no difference in the energy expenditure was found between the red-pepper diet period and the control diet period. However the carbohydrate oxidation was significantly higher in the red-pepper diet period than in the control diet period while the lipid oxidation was lower in the red-pepper diet period than in the control diet period for 150 min after the meal. In the second experiment, the subjects consumed a breakfast with 10g of red pepper after an oral administration of propranolol or a placebo. The propranolol abolished the increase in energy expenditure during the initial 30 min due to the meal containing red pepper. For the remaining 120 min, no difference in energy expenditure was found between the propranolol period and the placebo period. These results suggest that an increase in the energy expenditure after the meal containing red pepper appeared only immediately after the meal ingestion and a red-pepper diet increases the carbohydrate oxidation without increasing total energy expenditure for 150 min after the meal. And an increase in the energy expenditure immediately after the meal containing

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red pepper is considered to be caused by \( \beta \)-adrenergic stimulation.

**Key Words**  red pepper, energy expenditure, substrate oxidation

Red pepper has been used as a common spice for enhancing the palatability of foods and medicinally as a counterirritant. Henry and Emery (1) investigated the effect of spiced food on the metabolic rate in men, and have shown that the metabolic rate was increased by 25\% when chili sauce and mustard sauce were added to a meal.

On the other hand, Kawada et al. (2) have reported that the capsaicin, which is a pungent component of red hot pepper, stimulates epinephrine secretion from the adrenal medulla of rats, and results in a rapid but transient elevation of the respiratory quotient (RQ) (3). They have also reported that these alterations in the energy metabolism by the administration of capsaicin are specifically inhibited by various \( \beta \)-adrenergic blockers such as propranolol, pindolol and atenolol (3). We therefore hypothesized that the increase in the energy expenditure after the meal containing red pepper could occur in men and it might be due to \( \beta \)-adrenergic stimulation. Thus, in this study, we examined the effects of a red-pepper diet on the energy expenditure and the substrate oxidation rate, and also examined whether or not these effects were dependent upon \( \beta \)-adrenergic stimulation which was similar to that observed in rats (3).

**METHODS**

**Experiment 1**

**Subjects.** Eight male long-distance runners were used for this experiment. All subjects agreed to participate in conformity with the Declaration of Helsinki. Their characteristics are presented in Table 1.

**Experimental protocol and measurements.** The experimental protocol for this study was focused on the contribution of dietary red pepper on the energy metabolism at rest. The subjects consumed a standardized dinner (P:F:C=15:25:60) on the previous evening. The next morning, they participated in one of the two test sessions consisting of the measurements of the energy expenditure and the

### Table 1. Characteristics of the subjects.

| Variable         | Exp. 1          | Exp. 2          |
|------------------|-----------------|-----------------|
|                  | M (n=8)   | SD  | M (n=7) | SD  |
| Age (year)       | 20.5       | 1.0  | 21.6    | 0.7  |
| Height (cm)      | 169.5      | 4.7  | 170.9   | 6.3  |
| Weight (kg)      | 58.5       | 5.6  | 61.3    | 11.6 |
| \( \dot{V}O_2 \) max (ml/kg/min) | 57.5 | 3.4  | 47.1    | 10.9 |

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carbohydrate and lipid oxidations for 150 min after the breakfast (P:F:C = 15:25: 60) either with or without 10g of red pepper (4). For 20 min after the subjects consumed the experimental meal, their expired gas was collected for 10 min (Time 30) using a Douglas bag. The next gas collections were performed every 10 min until 90 min after the meal and then every 30 min from 90 min to 150 min after the meal. The pulmonary ventilation and the fraction of O2 and CO2 in the expired gas were measured with a spirometer (Fukuda Irika Kenkyujo CR-20) and paramagnetic and infrared analyzers (Perkin Elmer 1100 Medical Gas Analyzer), respectively. The lipid and carbohydrate oxidation rates were estimated by using the tables of Lusk (5), while assuming that 10% of the resting metabolic rate (RMR) is covered by the protein oxidation in post-absorptive conditions, as previously described (6).

Experiment 2

Subjects. Seven males were used for this experiment. All subjects agreed to participate in conformity with the Declaration of Helsinki. The characteristics of the subjects are also presented in Table 1.

Experimental protocol and measurements. The experimental protocol for this study was aimed at evaluating the inhibitory effect of the β-adrenergic blocker on the energy expenditure after a meal containing red pepper in male individuals. The subjects consumed a standardized dinner with either propranolol (50 mg) or a placebo on the previous evening. The next morning, they took the same pill as the previous evening and then participated in the test sessions during which the energy expenditure and the substrate oxidation rate were measured for 150 min after the red-pepper meal. The procedures used for gas collection and the estimation of the lipid and carbohydrate oxidation rates were exactly the same as those used in Experiment 1.

Statistics

The data were analyzed by two-way ANOVA for each experiment. The significant differences between the red-pepper diet and the control diet in the Experimental 1 and between β-blocker and placebo in Experiment 2 at each time point were analyzed by the paired Student's t-test. Differences were considered to be statistically significant at p < 0.05.

RESULTS

Energy expenditure (Fig. 1)

In Experiment 1, the energy expenditure tended to be higher with the red-pepper diet than with the control diet during the initial 30 min after the meal. For the remaining 120 min, no difference was found between the red-pepper diet period and the control diet period. In Experiment 2, propranolol abolished the increase in energy expenditure due to the meal containing red pepper during the initial 30 min after the meal. For the remaining 120 min, no difference was found between propranolol and the placebo.
Fig. 1. The energy expenditure for 150 min after the oral ingestion of a meal either with or without red pepper at rest in men in Experiment 1 (n = 8) and after the oral administration of propranolol or a placebo with the meal containing red pepper at rest in men in Experiment 2 (n = 7). The values are the means of each experiment.

**Respiratory quotient** (Fig. 2)

In Experiment 1, the respiratory quotient was higher with the red-pepper diet than with the control diet. In Experiment 2, no difference was found between propranolol and the placebo.

**Carbohydrate oxidation** (Fig. 3)

In Experiment 1, carbohydrate oxidation was higher with the red-pepper diet than with the control diet. In Experiment 2, no difference was found between propranolol and the placebo.

**Lipid oxidation** (Fig. 4)

In Experiment 1, the lipid oxidation was lower with the red-pepper diet than
Fig. 2. The respiratory quotient for 150 min after the oral ingestion of a meal either with or without red pepper at rest in men in Experiment 1 (n=8) and after the oral administration of propranolol or a placebo with a meal containing red pepper at rest in men in Experiment 2 (n=7). The values are the means of each experiment.

with the control diet. In Experiment 2, no difference was found between propranolol and the placebo.

DISCUSSION

In this study, we investigated the effects of dietary red pepper on the energy expenditure and on substrate oxidation and whether or not the alteration in energy expenditure and substrate oxidation by a meal containing red pepper were dependent upon β-adrenergic stimulation.

Henry and Emery (1) determined that the effects of spiced food on the diet induced thermogenesis (DIT) and have reported that spiced food containing chili sauce and mustard sauce caused a 44% increase in the energy expenditure at 15 min

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Fig. 3. The carbohydrate oxidation for 150 min after the oral ingestion of a meal either with or without red pepper at rest in men in Experiment 1 (n=8) and after the oral administration of propranolol or a placebo with the meal containing red pepper at rest in men in Experiment 2 (n=7). The values are the means of each experiment.

after the meal while only a 15% increase for the control meal. They have also discussed a possible mechanism by which the DIT was increase by the spiced food, and have suggested the participation of the pungency of the spiced food, because the principle pungent agent in chili has been identified to be capsaicin while that found in mustard is allyl isothiocyanate (7). Kawada and coworkers have also reported that capsaicin enhances catecholamine secretion from the adrenal medulla in rats (2,8-10) mainly through activation of the central nervous system (11), and results in a 23% increase in oxygen consumption (3). In our studies, we used red hot pepper which contains approximately 3 mg of capsaicin per g (4). In Experiment 1, the red-pepper diet showed a 27% increase in oxygen consumption immediately after the meal while only a 15% increase (data not shown) for the control diet. Moreover, the red-pepper diet showed a 32% increase in the energy.
expenditure immediately after the meal compared to the control diet period, which showed only a 9% increase. However, for the remaining 120 min, no difference in the energy expenditure was found between the red-pepper period and the control period. These findings were consistent with the previous studies (3), which used an intraperitoneal injection of capsaicin at a level of 6 mg/kg body wt in rats and showed an increase of approximately a 25% in energy expenditure (estimated from their RQ and oxygen consumption) immediately after the injection. The energy expenditure returned to the basal level at 60 min and remained at that level until 180 min. It had been reported that 80% of the capsaicin, when ingested orally, was absorbed gradually and eventually appeared in the bloodstream (12). Furthermore, Watanabe et al. (11) have reported that capsaicin was found to induce a
dose-dependent increase in adrenal nerve activity when injected intraperitoneally from 20 to 200 μg capsaicin/kg body wt. We propose that the effects of capsaicin (red pepper) in this study were less dramatic compared to Kawada's study (3) possibly due to the fact that we used a lower amount of capsaicin (approximately 0.5 mg/kg body wt) and our subjects ingested the capsaicin orally with an experimental meal.

The RQ in the red-pepper period was significantly increased for 100 min starting at 50 min after the meal and there was a significant difference between the red-pepper diet and the control diet in Experiment 1. It has been shown that the RQ was immediately increased when capsaicin was intraperitoneally injected to rats at a dose of 6 mg/kg body wt (3). However, the value returned to the basal level within 90 min and started to decline by 120 min after the injection (3). We consider that the difference between these two studies may be due to the differences in the feeding designs: (1) The effect of previous high fat feeding on substrate utilization still may exist in their study; (2) we served a high carbohydrate diet. In addition, it has been reported that there are differences in the regulation of lipolysis in the adipose tissue between rats and humans (13).

In Experiment 1, the carbohydrate oxidation rate was gradually increased after the meal containing red pepper and there was a significant difference between the red-pepper diet and the control diet. With the red-pepper diet, the lipid oxidation rate was immediately increased after the meal. However, for the remaining 120 min, the value was decreased in contrast to the carbohydrate oxidation rate. The difference was statistically significant between the red-pepper diet and the control diet from 70 min to 150 min after the meal. In light of the substrate oxidation rate from the previous study (3), their carbohydrate oxidation rate was increased immediately and then returned to the basal level within 120 min and then decreased to approximately 50% of the baseline level. However, the lipid oxidation rate showed a small change in comparison to the carbohydrate oxidation rate. The differences in the responses between their study and ours may be caused by the different methods of the capsaicin administration. In their study, the serum glucose concentration was significantly increased while the glycogen level in the liver was significantly decreased at 30 min after the injection in rats. Moreover, the serum glucose level reached 476 mg/dl at 120 min after the injection. This appeared to be a maximal response in a physiological situation. Thus, the dramatic and immediate response of the carbohydrate oxidation rate in their study might be due to greater mobilization of the fuel for carbohydrate oxidation.

Kawada and coworkers (3) have reported that rats previously injected with a β-adrenergic blocker (propranolol, 3.0 mg/kg body wt) showed inhibition of the red pepper-induced alteration in the oxygen consumption and the RQ by the injection of capsaicin (6.0 mg/kg body wt), indicating that the β-adrenergic blocker abolished this alteration in energy expenditure. In Experiment 2, the β-blocker nullified any increase in the energy expenditure due to the meal containing red pepper immediately after the meal, but during the remaining 120 min, no difference was found.
between the β-blockade period and the placebo period. In addition, this alteration by β-blockade with the red-pepper diet was similar to that with the control diet in Experiment 1. On the other hand, the RQ, the carbohydrate oxidation rate and the lipid oxidation rate showed no significant difference between the β-blockade period and the placebo period. Therefore, these results suggest that other factors besides β-adrenergic stimulation, such as α-adrenergic stimulation, might contribute to the alteration of the substrate utilization after the administration of the red-pepper diet in men. It has been shown that α₁-receptors are also mediators of epinephrine and norepinephrine stimulation of glycogenolysis in the adipocytes (14,15) and in the liver (16–18), and that α₂-receptors inhibit lipolysis in human adipose tissue (19, 20). In addition, norepinephrine at physiologic concentrations has been shown to bind primarily to α-receptors (21,22). However, the detailed mechanisms of these actions remain to be clarified.

In summary, we examined the effects of dietary red pepper on the carbohydrate and lipid oxidation rates at rest in men, and showed that: (1) an increase in the energy expenditure after the meal containing red pepper appeared but only immediately after the meal ingestion; (2) during the period following a red-pepper meal, changes in the substrate oxidation were observed without affecting energy expenditure; and (3) the increase in energy expenditure immediately after a meal containing red pepper was caused by β-adrenergic stimulation; however, the changes in substrate oxidation was not considered to be dependent upon β-adrenergic stimulation in men.

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