Effects of Combination of Regular Exercise and Tea Catechins Intake on Energy Expenditure in Humans

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Improvement in dietary habits and regular exercise is considered to be effective in preventing and/or reducing obesity and lifestyle-related diseases. The aim of this study was to analyze the effects of the combination of regular exercise and tea catechins intake on energy expenditure in humans. Fourteen healthy male subjects of 26 to 42 years of age received either a test beverage containing tea catechins or a control beverage without tea catechins for 2 months period; during this period they also engaged in treadmill exercise at a pace of 5 km/hr for 30 min 3 times a week. Energy expenditure in a sedentary condition or during the treadmill exercise was measured after 2 months by indirect colorimetry. Fat utilization for energy expenditure under both sedentary and exercising conditions was significantly increased by the combination of regular exercise and tea catechins intake compared to that by exercise alone.

Key words —— tea catechin, energy expenditure, respiratory quotient, regular exercise

INTRODUCTION

Improvements in dietary habits and regular exercise are important for preventing and/or reducing obesity or lifestyle-related diseases, and their effectiveness depends on the balance between energy intake and expenditure.[1)]

Focusing on the antiobesity effects of tea catechins, we have analyzed the effects of tea catechins intake from the viewpoint of diet therapy. Nagao *et al.*[2)] demonstrated that visceral fat was reduced by long-term intake of tea catechins in humans. We reported on a murine model[3)] suggesting that tea catechins could stimulate lipid metabolism in the liver and suppress visceral fat accumulation. It is speculated that tea catechins intake or regular exercise modulates energy balance by increasing the utilization of body fat for energy expenditure. It is anticipated, therefore, that tea catechins intake in combination with regular exercise may effectively stimulate energy metabolism and thereby suppress the onset of obesity or lifestyle-related diseases.

The present study was performed as part of our series of studies on the effectiveness of tea catechins, to analyze the effects of the combination of tea catechins intake and regular exercise on energy expenditure in humans.

MATERIALS AND METHODS

Study Subjects —— Fourteen healthy male volunteers of 26 to 42 years of age were enrolled in this study. This study adhered to the spirit of the Declaration of Helsinki with adequate cautions under the supervision of a physician. Written informed consent was obtained from volunteer subjects who were fully informed on the details and methods of this study.

During the study period, the subjects were instructed not to change their daily exercise intensity or daily diet.

Materials —— The subjects received a beverage in the form of a sports drink of 500 ml. As the test beverages for this study, a sports drink containing 570 mg of tea catechins, and a control sports drink lacking the tea catechins but containing other compounds at the same concentrations were prepared. Both bev-

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Table 1. Catechin Compositions of the Test Beverages (mg/500 ml)

	Control	Catechin
Catechin	0.0	12.7
Epicatechin	0.0	49.7
Gallocatechin	0.0	36.0
Epigallocatechin	0.0	174.7
Catechin gallate	0.0	4.1
Epicatechin gallate	0.0	65.7
Gallocatechin gallate	0.0	9.1
Epigallocatechin gallate	0.0	218.4
Total	0.0	570.4

erages contained sweeteners (such as sugar or sugar alcohol), acidulants (such as citric acid), electrolytes (such as Na or K salts), antioxidants and flavor. The pH, calorie, Na and caffeine concentrations in these test beverages were adjusted to 3.5, 5 kcal/100 ml, 42 mg/100 ml and below 8 mg/100 ml, respectively. The composition of the tea catechins in the test beverage is shown in Table 1.

Study Design —— The subjects were divided into two groups (control group, $n = 7$; catechin group, $n = 7$) so that their data of body mass index (BMI) and indirect calorimetric profile were comparable on a group basis. During the study period, they ingested 500 ml of either the catechin-containing beverage or the control beverage every day for 2 months, and engaged in a treadmill exercise at a pace of 5 km/hr for 30 min 3 times a week. On the days of walking exercise (3 days a week), they ingested 500 ml of either the catechin-containing beverage or the control beverage within 1 hr before or after walking. After the 2-month intake of the test beverages, indirect calorimetric analysis was performed to measure energy expenditure under sedentary and exercising (*i.e.*, on the treadmill) conditions.

From 2 days before the indirect calorimetric analysis, the subjects took specified meals for breakfast, lunch and dinner (total calorie: 2200 kcal/day; total fats: 55 g/day). During these 2 days, they were not allowed to consume any alcoholic drink, and were instructed to refrain from eating between meals. After dinner on the day before the indirect calorimetric analysis, intake of food or drink except water was prohibited (13-hr fasting).

On the day of the indirect calorimetric analysis, water intake was prohibited from 2 hr before entering the measuring room, and any physical activity such as climbing stairs that might affect the indirect calorimetry was also prohibited. Indirect calorimetry was measured in a room maintained at a constant temperature and humidity of 22°C and 40%, respectively, using the VO2000 metabolic testing system (Medical Graphics Corporation: U.S.A.). After entering the room, subjects became acclimatized in a sedentary position for 30 min, and then ingested 500 ml of the catechin-containing test beverage or the control beverage within 3 min. After the ingestion, indirect calorimetric analysis was performed in the exercising condition for 30 min while they were walking on the treadmill at a pace of 5 km/hr, followed by another 30-min indirect calorimetric analysis in a sedentary position with eyes closed.

Statistical Analysis —— The obtained data are represented as mean values ± standard deviations. The significance of inter-group differences was determined by the unpaired *t*-test. The level of significance was set to $p < 0.05$.

RESULTS AND DISCUSSION

The mean initial values of body weight and BMI in the control and catechin groups, which were measured at the start of this study, were 68.4 ± 11.9 and 73.5 ± 7.1 kg, and 23.1 ± 3.8 and 24.5 ± 2.6 kg/m^2, respectively, showing no significant differences between the groups.

To obtain background data for each subject, indirect calorimetric analysis was performed for 30 min under sedentary and 13-hr fasting conditions before the start of this study. In Table 2, the initial values of energy expenditure and respiratory quotient in the sedentary condition are shown. No significant difference was observed in total energy expenditure, carbohydrate and fat oxidation and respiratory quotient between the control and catechin groups.

After regular intake of the test beverages (500 ml/day) and regular exercise on the treadmill (3 times a week) for 2 months, indirect calorimetric analysis was performed. Table 3 shows the evaluation parameters relevant to energy expenditure in the sedentary condition, calculated from indirect calorimetric analysis data obtained during a period of 30 min after the intake of the test beverages. There was no significant difference in total energy expenditure in the sedentary conditions between the control and catechin groups. However, the catechin group showed a significantly lower carbohydrate

Table 2. Characteristics of Subjects before Test Beverage Administration[a)]

	Control	Catechin	$p^{b)}$
Energy expenditure (kcal/day)	1956 ± 563	1878 ± 426	NS
Carbohydrate oxidation (kcal/day)	299 ± 174	271 ± 185	NS
Fat oxidation (kcal/day)	1420 ± 554	1501 ± 647	NS
Respiratory quotient	0.75 ± 0.03	0.74 ± 0.05	NS

a) Means ± S.D., $n = 7$, *b*) For differences across treatments (Student's *t*-test).

Table 3. Energy Expenditure, Substrate Oxidation, and Respiratory Quotient in Sedentary Subjects[a)]

	Control	Catechin	$p^{b)}$
Energy expenditure (kcal/day)	1936 ± 271	2026 ± 274	0.5473
Carbohydrate oxidation (kcal/day)	612 ± 276	334 ± 139	0.0350
Fat oxidation (kcal/day)	997 ± 240	1365 ± 273	0.0201
Respiratory quotient	0.81 ± 0.04	0.77 ± 0.02	0.0174

a) Means ± S.D., $n = 7$, *b*) For differences across treatments (Student's *t*-test).

Table 4. Energy Expenditure, Substrate Oxidation, and Respiratory Exchange Ratio during the Treadmill Exercise[a)]

	Control	Catechin	$p^{b)}$
Energy expenditure (kcal/day)	7301 ± 1030	8103 ± 849	0.1072
Carbohydrate oxidation (kcal/day)	3012 ± 1062	2553 ± 1158	0.3424
Fat oxidation (kcal/day)	3956 ± 1305	5217 ± 904	0.0288
Respiratory exchange ratio	0.83 ± 0.04	0.80 ± 0.03	0.1187

a) Means ± S.D., $n = 7$, *b*) For differences across treatments (Student's *t*-test).

oxidation under sedentary conditions than the control group after test beverage ingestion. On the other hand, in the catechin group, the fat oxidation in the sedentary condition was about 1.4-fold that of the control group, showing a significant inter-group difference. The respiratory quotient under sedentary conditions in the catechin group was significantly lower than that in the control group.

Table 4 shows the data of energy expenditure during the 30-min treadmill exercise, obtained following the indirect calorimetric analysis under sedentary conditions. No significant difference was observed in total energy expenditure in the exercising condition between the control and catechin groups. Also, no significant difference was observed in carbohydrate oxidation in the exercising condition between the control and catechin groups. However, the catechin group showed a significantly higher fat oxidation in the exercising condition than the control group. No significant difference was observed in respiratory exchange ratio in the exercising condition between the control and catechin groups, although the catechin group showed a slightly lower value.

From these results, it was demonstrated that the fat oxidation was increased in both the sedentary and exercising conditions by tea catechin intake in combination with 3-times weekly walking exercise. In the present study, indirect calorimetric analysis was performed under the condition of overnight fasting; therefore, the proportion of dietary fat-derived chylomicron, which is an energy source for fat utilization, was low. Thus, it was considered that body fat-derived lipid metabolism mainly occurred under such conditions. It has been reported that oxidative degradations of free fatty acids are increased in the liver and muscle tissues by the increased lipolysis of adipose tissues, which is a factor for increased utilization of body fat as an energy source.[4)] We reported that the tea catechins might contribute to an increase in body fat utilization for energy expenditure.[5)] We have also found that fatty acid oxidation in the liver and skeletal muscles was increased in mice by a combination of regular exercise and tea catechins intake more effectively than by the exercise or tea catechins intake alone (submitted for publication).

Therefore, it is considered that body fat utilization for energy expenditure may be increased in humans as a consequence of the stimulation of lipid metabolism in the liver or skeletal muscles by a combination of tea catechins intake and regular exercise at a frequency of 3 times a week.

In conclusion, it was found that body fat utilization for energy expenditure was more effectively increased in both sedentary and exercising conditions by the combination of tea catechins intake and regular exercise than by the exercise alone. Thus, a combination of regular exercise and tea catechins intake can be expected to reduce body fat efficiently. The obesity-improving effects of tea catechins intake in combination with exercise in humans remain to be further investigated.

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