ORIGINAL

Oolong tea increases energy metabolism in Japanese females

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Abstract : Oolong tea is a traditional Chinese tea that has long been believed to be beneficial to health such as decreasing body fat. We were interested in this assertion and tried to evaluate the effect of oolong tea on energy expenditure (EE) in comparison with green tea. The subjects were eleven healthy Japanese females (age 20±1 y; body mass index (BMI) 21.2±2.5kg/m^2)who each consumed of three treatments in a crossover design : 1) water, 2) oolong tea, 3) green tea. Resting energy expenditure (REE) and EE after the consumption of the test beverage for 120 min were measured using an indirect calorimeter. The cumulative increases of EE for 120 min were significantly increased 10% and 4% after the consumption of oolong tea and green tea, respectively. EE at 60 and 90 min were significantly higher after the consumption of oolong tea than that of water (P<0.05). In comparison with green tea, oolong tea contained approximately half the caffeine and epigallocatechin galate, while polymerized polyphenols were double. These results suggest that oolong tea increases EE by its polymerized polyphenols.
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INTRODUCTION

Oolong tea is a traditional Chinese tea that is also popular in Japan. In China, oolong tea has long been believed to be beneficial to health (1). A recent study with 102 Chinese females showed that continuous consumption of oolong tea for 6 wk led to body weight reduction (2). Food related weight reduction is mainly by two mechanisms : one is the increase in energy expenditure (EE) and the other is the inhibition of nutrient absorption. Major components of oolong tea are polyphenols, caffeine and amino acids (3). There are many studies that show the increase of EE by caffeine in rodents (4, 5) and humans (6-14). Whether the increase in EE that accompanies the consumption of oolong tea is due solely to caffeine or other constituents such as polyphenolic compounds is controversial (15, 16).

Green tea and oolong tea are produced from a single plant species, but are distinguished by the processing technique. For the production of green tea, the leaves are steamed soon after the harvest to stop the enzyme reactions and then ground by hand to break the cells of the leaves. On the other hand for the production of oolong tea, the leaves are kept under certain conditions to produce spe-

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cific flavors by enzyme reactions (fermentation). The specific flavors of the fermented tea are due to the polymerized polyphenols. The leaves of oolong tea are not ground and the leaf cells are not broken. By these differences in the processing, the components of green tea and oolong tea are different. In Japan, powdered green tea is also popular and used for tea ceremonies. The present was designed to assess whether the consumption of oolong tea increase EE in comparison with green tea.

SUBJECTS AND METHODS

Study design

The treatments were 1) water, 2) oolong tea and 3) green tea. All subjects took water treatment on the first day. Then they were randomly divided into two groups, and assigned to oolong tea or green tea treatment in a crossover design.

Subjects

Eleven healthy young women were recruited from the student population majoring in nutrition at a university. Medical and nutritional histories were obtained by use of a questionnaire. Smokers and those who engaged in intense physical activities or had a history of weight loss were not included in the current study. At the onset of the study, body weight and height were measured. Mean (± SD) values for some of the physical characteristics of the subjets were as follows : age, 20±1y ; height 163.4±0.9 cm (160.5-168.1) ; weight, 56.3±2.3 kg (47.2-68.6) ; and body mass index (BMI) 21.1±0.8 kg/m^2 (18.2-25.9). With the consideration of physiological differences in menstrual cycle, we carried out the study when the subjects were in the follicular phase. The subjects gave their written informed consent to participate in the study. The University of Tokushima Committee for Studies involving Human Subjects, approved all procedures.

Experimental design

Subjects consumed a standardized meal (600 kcal, 28 g protein, 15 g lipids) between 19 : 00-20 : 00 on the day preceding each session. They were allowed to take only water after the meal. They stayed at the metabolic ward. The time schedule at the metabolic ward was as follows : bed at 23 : 00 on the previous night, rising at 6 : 00, toilet, rest in a reclining chair for 30 min, collection of expired gas for 5 min to measure resting energy expenditure (REE), consumption of the test beverage in 5 min, collection of expired gas for 5 min followed by the consumption every 30 min for 120 min to measure EE in the resting condition. For the measurement of EE, expired gas was collected in a Douglas bag, the volume was measured with a gas meter, and carbon dioxide and oxygen contents were analyzed with a gas monitor (RE 3000, Fukuda Denshi Co., Tokyo, Japan).

Oolong tea was obtained from Suntory Ltd (Osaka, Japan) prepared in bags containing 15 g of tea leaves per bag. The tea was brewed by adding 300 ml of boiling distilled water to a glass container containing the tea bag. The tea was steeped for 5 min, and the bag was then removed. Green tea was obtained from Suntory Ltd (Osaka, Japan) prepared with 5 g of powdered green tea, and dissolved in 300 ml of boiling distilled water. Tea for all subjects was prepared each morning and cooled to 37°C before drinking. The strength of teas used in this study was well accepted by the subjects.

Analyses of caffeine, flavanols and other polyphenols

Concentration of caffeine, flavanols and other polyphenols (fractions including polymerized flavanols and other flavonoids) in the oolong tea and the green tea were analyzed by HPLC with UV detection at 280 nm (17). Analysis was performed with a Cosmosil 5PE-MS column (4.6 mm i.d.×150 mm ; Nakarai Tesque, Kyoto, Japan) at 40°C. Compounds were eluted (eluent A : 0.05% trifluoroacetic acid in water ; eluent B : 0.05% trifluoroacetic acid in acetonitrile) at a flow rate of 2 mL/min using a gradient program (eluent B content : 10% for 5 min, from 10% to 21% in 8 min, from 21% to 90% in 1 min and 90% for 6 min). The quantification of caffeine, flavanols and other polyphenols was determined using standard calibration curves for known compounds purchased commercially : caffeine was from Nakarai Tesque Inc. (Kyoto, Japan). Epigallocatechin (EGC), catechin (C), epicatechin, epigallocatechin gallate (EGCG), gallocatechin gallate (GCG), epicatechin gallate (ECG) and catechin gallate (CG) were from Kurita Water Industries LTD (Tokyo, Japan). Other polyphenols were quantified using a calibration curve that was derived from polyphenols, which had been isolated from tea by HPLC.

Table 1 shows all analyzed components including caffeine, individual catechins and other polyphenols. The lower-case concentrations of caffeine and EGCG were approximately half in the oolong tea (77 mg/

300 ml and 81 mg/300 ml, respectively) compared with those in the green tea (161 mg/300 ml and 156 mg/300 ml, respectively), while the concentration of polymerized polyphenols was much higher in the oolong tea (68 mg/300 ml) than that in the green tea (17 mg/300 ml). For the concentrations of the other polyphenols, there was no marked difference between the oolong tea and the green tea.

Statistics

All values were expressed as means±SE and analyzed using a procedure from SAS/ATAT software, version 8, of the SAS system for personal computers (SAS Institute, Cary, NC). Since we had a small number of subjects, statistical comparisons were made by ANOVA. Significant differences in EE and RQ among treatments were determined by the Tukey-Kramer test and repeated measurements in each treatment were determined using the paired *t* test with the comparison to the REE level. Differences were considered to be significant at $P<0.05$.

RESULTS

Fig. 1 shows the REE and EE measured for 120 min following the consumption of water, green tea or oolong tea. REE were similar among the 3 treat-

Table 1. Analysed composition of oolong tea and green tea consumed by subjects (mg/300 ml)

	Oolong tea[1]	Green tea[2]
Caffeine	77	161
Epigallocatechin (EGC)	78	94
catechin (C)	6	4
epicatechin (EP)	22	10
epigallocatechin gallate (EGCG)	81	156
gallocatechin gallate (GCG)	3	2
epicatechin gallate (ECG)	16	26
catechin gallate (CG)	0	1
polymerized polyphenol	68	17

[1] 15 g oolong tea was steeped in 300 ml hot water for 5 min.
[2] 5 g powdered green tea were dissolved in 300 ml hot water.

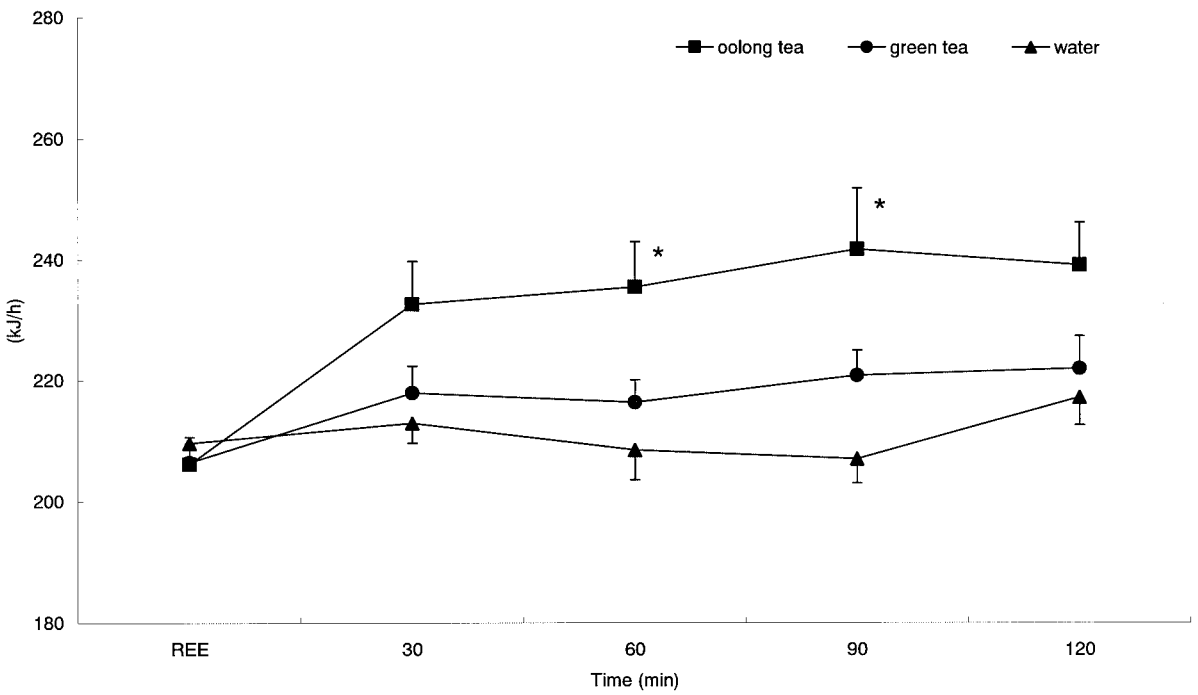

Fig. 1. Resting Energy Expenditure (REE) and Energy Expenditure following the consumption of water, green tea or oolong tea for 120 min.
Values are means±SE ; P values were determined by Tukey-Kramer test.
*Significant difference at $P<0.05$.

ments (206.6±3.7, 207.8±4.1 and 211.2±3.7 kJ/h for oolong tea, green tea and water treatment, respectively). While EE after the consumption of water was constant around the REE level for 120 min, EE after the consumption of oolong tea or green tea were increased immediately (EE at 30 min : P<0.01) and gradually up to 90 min, then maintained until 120 min. The maximum value of EE after the consumption of oolong tea and green tea were at 90 min : 237.3±10.1 and 223.2±3.9 kJ/hr, respectively. The values of EE at 60 and 90 min after the consumption of oolong tea were significantly higher than those after the consumption of water (P<0.05). The cumulative increases of EE after the consumption of oolong tea, green tea or water above REE was 110.7±17.7, 49.5±0.4 and 11.2±1.1 kJ/2 h, respectively.

Fig. 2 shows the variations of non-protein respiratory quotients (RQ). RQ at the measurement of REE was not significantly different among the treatments (0.82±0.01, 0.81±0.01 and 0.82±0.01 for oolong tea, green tea and water treatment, respectively) and stayed constant until the end of the measurement in 3 treatments.

DISCUSSION

The major components of oolong tea and green tea were caffeine and polyphenols (Table 1). Caffeine is well known to increase EE (4-14). Recently, Rumpler *et al.* (16) compared 24-h EE of those who consuming oolong tea with that of those who consumed water containing 270 mg caffeine, which was equivalent to the concentration in the tea, and observed that while EE was increased 2.9% for the oolong tea, it was increased 3.4% for the caffeinated water. From this result, they suggested that the caffeine was the main factor in causing the increase of EE. In contrast, Dulloo *et al.* (15) reported that the consumption of water containing 150 mg caffeine did not affect the 24-h EE, while the consumption of green tea extract which contained equivalent amounts of caffeine elevated 24-h EE 4% above the water alone. From the result they suggested that EGCG, which constituted about 70% of total catechins, was the major factor in causing the increase of EE.

In the current study, the subjects consumed the test beverages without a meal and measured the EE for 2 h. Since the metabolism of caffeine and polyphenols are swift, the plasma caffeine peaks at 1 h (18) and plasma polyphenols peaks at 3 h (19), the effect of these tea components on EE can be observed more clearly when the test beverage is administratered alone and the EE can be determined at the expected time when the tea components reached their peak level. If might be better to measure the EE after more than 2 h, because the EE

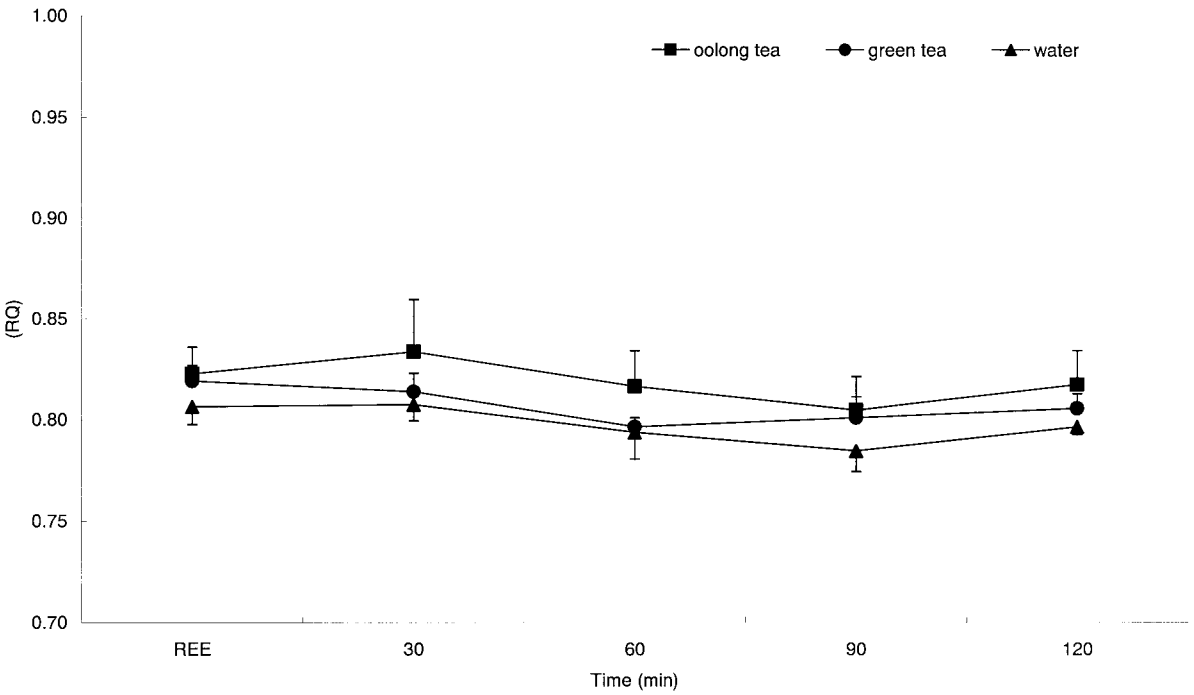

Fig. 2. Variations of non-protein respiratory quotients (RQ).
Values are means±SE ; P values were determined by Tukey-Kramer test.

after the consumption of oolong tea kept increasing after 2 h. However, the 2 h was the maximum length to measure the EE when we used the indirect calorimeter with the fasting condition. As shown in the results, oolong tea increased EE and the effect was about double that of green tea. Since concentrations of caffeine and EGCG in oolong tea were about a half of those in green tea, this suggested that not only caffeine or EGCG, but also the other components of oolong tea enhanced EE. Major polyphenols of oolong tea are polymerized polyphenols produced by its unique fermentation. In the current study, the concentration of total polymerized polyphenols in oolong tea (68 mg/300 ml) was much higher than that in green tea (17 mg/300 ml). These results suggest that polymerized polyphenols might be the major factor in causing the increase of EE by oolong tea. Dulloo *et al.* (20) showed that catechin-polyphenols affect the sympathetic stimulation of thermogenesis by inhibiting the enzyme catechol-*O*-methyltransferase. This mechanism on the thermogenic effect of catechin-polyphenols is different from that of caffeine, accordingly, the synergistic interection between catechin-polyphenols and caffein is suggested. Since there has been only a few studies that determined the thermogenic effect of the polyphenols and we have not been able to specify the polymerized polyphenol(s) that affected EE, further studies are needed to confirm the mechanism that led to the larger increase of EE with the consumption of oolong tea.

In the studies of both Dulloo (15) and Rumpler (16), they observed an enhancement of the substrate oxidation after the consumption of those teas. Dulloo (15) reported a small increase in fat oxidation with the consumption of 150 mg caffeine but a much greater increase with the consumption of green tea (33%), indicating that the catechin content of the tea stimulated the fat oxidation. Rumpler (16) observed a greater increase in fat oxidation with the consumption of oolong tea (12%) than that with the consumption of 270 mg caffeine (8%). In the present study, however, the RQ values were not different among the treatments and remained constant throughout the study period (Fig. 2). The present measurement of RQ for 2 h might be too short to determine the impact of the tea on fat oxidation.

The effect of oolong tea on nutrient absorption may be an important factor on the weight reduction. There are some studies that showed the inhibition of fat (21, 22) and carbohydrate absorption (23). Other studies on this topic would be desirable.

In conclusion, there were some limitations in the current study, but the results suggested that oolong tea increased EE and the factor was not only caffeine or EGCG but also some kinds of polymerized polyphenols.

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