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## Effectiveness of green tea on weight reduction in obese Thais: A randomized, controlled trial

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### Abstract

This study was undertaken to investigate the effects of green tea on weight reduction in obese Thais.

A randomized, controlled trial involving 60 obese subjects (body mass index, BMI > 25kg/m<sup>2</sup>) was conducted. All subjects consumed a Thai diet containing 3 meals (8373.6kJ/day) for 12weeks, prepared by the Nutritional Unit at Srinagarind Hospital. The diet contained 65% carbohydrates, 15% protein, and 20% fat. Body weight, BMI, body composition, resting energy expenditure, and substrate oxidation were measured at baseline, and during weeks 4, 8, and 12 of the study. Serum levels of leptin and urine VMA were measured at baseline and during the 12th week. Differences over time and between the treatments (green tea or placebo) over time were determined using two-factor ANOVA with repeated measures.

In comparing the two groups, differences in weight loss were 2.70, 5.10, and 3.3kg during the 4th, 8th, and 12th weeks of the study, respectively. At the 8th and 12th weeks of the study, body weight loss was significantly different ( $P < 0.05$ ). At the 8th week, the difference in resting energy expenditure was 183.38kJ/day ( $P < 0.001$ ), the difference in the respiratory quotient was 0.02 ( $P < 0.05$ ), and no significant differences existed in satiety score, food intake, or physical activity. Urine VMA was significantly different in the 12th week of the study ( $P < 0.05$ ).

We conclude that green tea can reduce body weight in obese Thai subjects by increasing energy expenditure and fat oxidation.

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**Keywords:** Obesity; Green tea; Thermogenesis; Catechins; Fat oxidation; Asia

### 1. Introduction

The prevalence of overweight and obesity is increasing worldwide, both in developing and developed countries [1]. Obesity is associated with an increased risk of chronic diseases, such as type 2 diabetes and cardiovascular disease, including hypertension [1]. In Asia, overweight is defined as body mass index (BMI) of 23–24.9kg/m<sup>2</sup>; obesity grade I is 25–29.9kg/m<sup>2</sup> and obesity grade II

is > 30kg/m<sup>2</sup> [2]. Currently, the effective treatment of obesity includes a reduced-energy intake, increased physical activity and exercise, behavior modification, pharmacotherapy, and surgery [1]. The maximal success rate of these treatments; however, is only 21%, and the most popular method for weight loss is pharmacotherapy [3].

Green tea is a herbal that contains two major active ingredients: 1) catechin polyphenol, which inhibits the action of catechol-*o*-methyl-transferase (COMT), resulting in a prolonged action of catecholamines and 2) caffeine, which inhibits the phosphodiesterase-induced degradation of intracellular cyclic AMP (cAMP)

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leading to an increase in norepinephrine release [4]; the net result, therefore, is an elevated cellular concentration of cAMP, a critical intracellular mediator for the action of catecholamines on thermogenesis [4–8]. Furthermore, catecholamines in the brain may play a major role in satiety [18,26]. Both catechin polyphenols and caffeine may be effective promoters of thermogenesis and fat oxidation, resulting in the reduction of body weight in Caucasians, Chinese, and Japanese [4–25]. Lipolytic activities between ethnic groups are different from non-esterified fatty acids [27,28]. Also, the components of native foods, in warm climates contain much more fat (35–40%) than in tropical areas (15–30%) [29,30]. Thus, the result of green tea function in Caucasians, Chinese, and Japanese may not be the same as in Thais or in inhabitants of tropical areas. We therefore studied whether green tea reduces body weight in obese Thais.

## 2. Subjects and methods

### 2.1. Subjects

Sixty Thai subjects were recruited from the officers of the Faculty of Medicine of Khon Kaen University. Complete medical and nutritional histories were obtained by questionnaires. Forty-two subjects were females and 18 subjects were males. Inclusion criteria included males between 40 and 60 years of age, females postmenopausal > 1 year, and a BMI > 25 kg/m<sup>2</sup>. Exclusion criteria included a history of: 1) a metabolic disease, such as diabetes mellitus, hyper- or hypo-thyroidism, and Cushing syndrome; 2) a systemic disease, such as heart, renal, or liver disease; 3) prescribed medications, such as antipsychotics, antidepressants, antiobesity medications, or hormonal therapy; 4) regular exercise or an average total energy expenditure > 8373.6 kJ/day; and 5) a history of tea or caffeine hypersensitivity. The subjects were equally randomized into two groups, the green tea group and the placebo group. All of the subjects gave their written informed consent. The study was approved by the Ethical Committee for Human Experimentation of Khon Kaen University.

### 2.2. Experimental design

The subjects in the green tea group received a 250 mg green tea capsule after breakfast, lunch, and dinner. The subjects in the placebo group received cellulose capsules, which were indistinguishable from the green tea capsules. During the experimental course, subjects had a regular diet (total energy, 8373.6 kJ/day) that was prepared by the Nutrition Unit of Srinagarind Hospital. The BMI, body composition, determination of resting energy expenditure (REE) and substrate oxidation, and visual analogue scales were measured at baseline and during the 4th, 8th, and 12th weeks. Measurement of urine VMA and serum leptin levels were collected at baseline and on the last day of the 12th week.

### 2.3. Green tea component analysis

The green tea capsule used was the Herbal One<sup>®</sup> brand. Each capsule was composed of green tea leaf extract (250 mg). The

manufacturer is Herbal One Co., Ltd. (Nakornprathom, Thailand). Extraction and high-pressure liquid chromatograph (HPLC) analysis were performed using the modified Sharma technique [31]. Greater than 10% of the products were randomly tested and their components differed by < 5%. Based on HPLC analysis, the extract consisted of 0.24 mg gallic acid, 4.09 mg catechin, 28.86 mg caffeine, 33.58 mg epigallocatechin gallate (EGCG), and 9.28 mg epicatechin gallate.

### 2.4. Measurements

#### 2.4.1. BMI

The subjects' heights were measured by using a wall-mounted ruler at the time of entry into the study. Body weights were measured using a digital scale before breakfast and after voiding, while wearing a standardized hospital gown. Body weights were measured at baseline, and during the 4th, 8th, and 12th weeks of the study. BMI was calculated as the weight in kilograms, divided by the height in meters squared. Thresholds of overweight and obesity were based on The Asia-Pacific Perspective Redefining Obesity, 2000 classification [2].

#### 2.4.2. Body composition

The distribution of fat was determined by measuring the waist and hip circumferences and by calculation of the waist-to-hip ratio. Waist and hip circumferences were measured using a standardized tape by the same well-trained staff. The tape was calibrated before use. The waist circumference was measured 1 in. above the umbilicus in the standing position. The hip circumference was measured at the site of the largest circumference between the waist and thighs. The waist-to-hip ratio was calculated by dividing the waist circumference by the hip circumference. Percent body fat was calculated by skinfold measurement. Skinfold measurement was measured using standardized calipers by the same well-trained staff. The calipers were calibrated before use. The sum of skinfold measurements of triceps, subscapular, and iliac were compared based on gender and age from the Jackson study [32] to calculate the percent body fat.

### 2.5. Dietary protocol

Each subject received a regular Thai diet prepared by the Nutritional Unit of Srinagarind Hospital that contained 3 meals (8373.6 kJ/day) for 12 weeks. This diet contained 65% carbohydrates, 15% protein, and 20% fat. All subjects were limited to the diet from the Nutritional Unit and recorded the amount of intake everyday. At the end of the study, the food record was calculated using a computerized Thai food program and reported in kJ/day.

### 2.6. Physical activity

The physical activities of the subjects were based on their usual routines and the subjects answered the 3 in 7 days physical activity recall questionnaire at baseline, and during the 4th, 8th, and 12th weeks of the study. The questionnaire used was the physical activity of diary living in 3 days that modified from The International Physical Activity Questionnaires (IPAQ).

The type and amount of exercise or activity was calculated by a computerized activity program to convert to the mean physical activity per day (kJ/day).

### 2.7. Visual analogue scales

Subjects rated their hunger and fullness on visual analogue scales [33]. For example, hunger was rated on a 100mm line preceded by the question, “How hungry are you right now?” and anchored by “not at all hungry” on the left and “extremely hungry” on the right. Other anchors consisted of the phrases “not at all” and “extremely” combined with the adjectives “full.” Ratings were completed before and every 30min for 3h after breakfast, lunch, and dinner. The ratings were assessed at baseline, and on the last day of the 4th, 8th, and 12th weeks of the study and then reported as the mean and SD.

### 2.8. Determination of resting energy expenditure and substrate oxidation

Energy expenditure was monitored by the bag technique of indirect calorimetry [10] at the beginning and the last day of the 4th, 8th and 12th weeks of the study. The Douglas bag system was validated by Raurich et al. method [35]. The monitoring was performed in the morning, 3h after breakfast, and the subjects rested 30min before monitoring. This technique was modified from Kovacs et al. [10]. All of subjects were measured one-by-one in a sitting position; the expired air was kept for 6min with thorough checking for air leakage. The air was removed continuously from the Douglas bag at the rate of 50 and 100L/min, and then passed through a mass flow meter for continuous measurement of the flow rate. The effect of pumping air out resulted in air entering the chamber through a special inlet placed in the wall opposite the location where the air exited. A fan was used to ensure that the air was mixed inside the chamber and a thermostat ensured the maintenance of a constant and comfortable temperature. Air samples entering and exiting the chamber passed through differential analyzers for continuous measurement of differences in oxygen and carbon dioxide content between the extracted and inlet air. These data were continuously fed into an on-line computerized data acquisition system, from which REE and the respiratory quotient (RQ) were calculated by indirect calorimetry (Powerlab; AD Instruments, Sydney, Australia). Gas analysis was performed by a Gas Analyzer (Model No. ML206; AD Instruments). Calculation of the REE was based upon Weir's formulae. The RQ was calculated as the CO<sub>2</sub> produced/O<sub>2</sub> consumed.

### 2.9. Blood pressure and heart rate

Systolic and diastolic blood pressures, and heart rate (SBP, DBP, and HR, respectively) were recorded during treatment at baseline, and during the 4th, 8th, and 12th weeks of the study in the resting state using an automatic blood pressure monitor (Citizen CH-403C, Tokyo, Japan).

Table 1  
Baseline characteristics

Character	Placebo group (n=30)	Green tea group (n=30)
Age (years)	48.95±4.96	48.53±5.50
Male	9	9
Female	21	21
Height (m)	1.59±0.08	1.61±0.12
Weight (kg)	71.90±11.70	69.30±9.54
BMI (kg/m <sup>2</sup> )	28.00±3.51	27.42±3.26
Body fat (%)	39.69±1.79	39.47±1.67
Waist (cm)	92.23±13.18	88.06±8.70
Hip (cm)	106.20±11.98	102.40±6.30
W/H ratio	0.86±0.06	0.86±0.05
REE (kJ/d)	7994.28±152.84	7978.91±104.08
RQ	0.84±0.05	0.84±0.07
SBP (mm Hg)	125.84±18.06	121.73±14.79
DBP (mm Hg)	79.73±12.43	80.26±10.63
HR (beat/min)	79.73±12.24	78.26±12.13
Leptin (ng/ml)	29.15±14.86	29.43±16.25
Satiety (mmVAS)	25.33±2.27	28.91±2.22
Urine VMA (mg/24 h)	5.54±1.67	5.48±1.32
The average left capsule (%)	8.36±4.54	9.31±4.67

Subjects matched for characteristics; no differences between groups were statistically significant by factorial ANOVA ( $P<0.05$ ).

(BMI = body mass index, W/H ratio = waist/hip ratio, REE = resting energy expenditure, RQ = respiratory quotient, SBP = systolic blood pressure, DBP = diastolic blood pressure, HR = heart rate, VMA= vanillylmandelic acid).

### 2.10. Measurement of urine vanillylmandelic acid (VMA)

The level of urine VMA was measured at the beginning of the study and during the 12th week. During the 12th week of the study, each subject was randomly tested for urine VMA. Twenty-four hour urine specimens were collected into opaque, plastic urine containers containing 30mL 6N HCl. All subjects had to avoid salicylates, caffeine, phenothiazine, antihypertensive agents, coffee, tea, chocolate, and fruit (especially bananas and any vanilla-containing substances) for 72h prior to collection. After the 24 h-collection period was complete; all urine samples were stored at  $-20^{\circ}\text{C}$  until assayed for VMA with an autoanalyzer by HPLC with electrochemical detection (HPLC-EDC).

### 2.11. Leptin level

Human leptin was measured by using leptin EIA kits (leptin EIA kit, Cayman Chemical, Michigan, USA), an immunometric EIA that permits leptin measurements within the range of 1–50ng/ml. Inter- and intra-assay CVs of  $<9\%$  can be achieved at most concentrations. Deionized water was used to prepare the reagents and samples. All samples were measured in duplicate according to the manufacturer's instructions.

### 2.12. Statistical analysis

Data are presented as the means and standard deviations. Data were analysed using STATA, version 8.0 (StataCorp, TX, USA). Differences over time and between the treatments (green tea or placebo) over time were determined using two-factor ANOVA with repeated measures. When appropriate, differences

Table 2  
Subject characteristics of the green tea ( $n = 30$ ) and the placebo ( $n = 30$ ) group at baseline, post-intervention 4, 8 and 12 weeks after treatment (mean values and standard deviations)

Outcome	Baseline				4 weeks				8 weeks				12 weeks			
	Green tea		Placebo		Green tea		Placebo		Green tea		Placebo		Green tea		Placebo	
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Weight (kg)	69.30	9.54	71.90	11.70	67.56	9.14	70.26	12.79	64.86 <sup>#</sup>	11.04	69.97 <sup>#</sup>	8.45	66.60 <sup>#</sup>	8.88	69.90 <sup>#</sup>	2.08
BMI (kg/m <sup>2</sup> )	27.42	3.26	28.00	3.51	25.94	2.37	27.14	3.78	24.39 <sup>#</sup>	1.70	27.01 <sup>#</sup>	2.82	24.45	4.50	26.12	4.77
Body fat (%)	39.47	1.67	39.69	1.79	36.57	1.44	36.91	1.95	32.25 <sup>#</sup>	3.13	36.67 <sup>#</sup>	1.30	35.67	1.80	36.92	3.90
Waist (cm)	88.06	8.70	92.23	13.18	86.70	7.57	89.06	11.23	81.46 <sup>#</sup>	7.70	86.43 <sup>#</sup>	8.57	84.20	11.31	88.0	10.17
Hip (cm)	102.40	6.30	106.20	11.98	100.23	4.98	102.33	7.86	99.73	6.18	100.80	6.70	100.40	5.59	101.00	2.82
W/H ratio	0.86	0.05	0.86	0.06	0.86	0.07	0.86	0.09	0.82 <sup>#</sup>	0.04	0.86 <sup>#</sup>	0.07	0.84	0.07	0.86	0.11
REE (kJ/d)	7978.91	104.08	7994.28	152.84	8135.20	176.99	8017.72	168.37	8351.12 <sup>#</sup>	187.74	8167.74 <sup>#</sup>	146.24	8234.31 <sup>*</sup>	126.18	8155.47	159.64
RQ	0.84	0.07	0.84	0.05	0.82	0.03	0.83	0.07	0.81 <sup>#</sup>	0.01	0.83 <sup>#</sup>	0.02	0.82	0.05	0.83	0.03
Food intake (kJ/d)	8413.92	50.68	8528.34	89.76	8160.07	105.79	8176.53	44.86	8070.73	66.15	8139.27	76.27	8743.00	28.46	8758.79	54.14
Physical activity (kJ/d)	1222.55	97.25	1205.80	67.48	1247.67	133.33	1243.48	107.56	1281.16	101.24	1239.29	135.16	1306.28	120.45	1256.04	167.71
Satiety (mm VAS)	28.91	2.22	25.33	2.27	32.84	1.98	32.73	3.02	34.63	1.45	35.98	1.45	36.62	2.65	35.93	2.38
Leptin (ng/ml)	29.43	16.25	29.15	14.86	—	—	—	—	—	—	—	—	25.44 <sup>*</sup>	12.26	26.24 <sup>*</sup>	10.50
Urine VMA (mg/24 h)	5.48	1.32	5.54	1.67	—	—	—	—	—	—	—	—	9.78 <sup>#</sup>	1.85	6.91 <sup>#</sup>	0.46

\*Mean value was significantly different to that at baseline ( $P < 0.05$ ) (repeated-measures ANOVA).

\*\*Mean value was significantly different to that at baseline ( $P < 0.001$ ) (repeated-measures ANOVA).

#Mean value was significantly different between groups,  $P$ -value over time, ( $P < 0.05$ ) (factorial ANOVA).

##Mean value was significantly different between groups,  $P$ -value over time, ( $P < 0.001$ ) (factorial ANOVA).

(BMI = body mass index, W/H ratio = waist/hip ratio, REE = resting energy expenditure, RQ = respiratory quotient, VMA = vanillylmandelic acid).

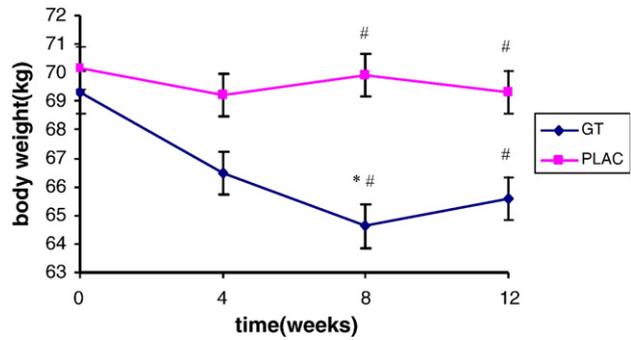


Fig. 1. Body weight of subjects in green tea group (GT) and placebo group (PLAC) at baseline, 4, 8 and 12 weeks after treatment. \*Mean value was significantly different to that at baseline ( $P < 0.05$ ) (repeated-measures ANOVA). #Mean value was significantly different between groups,  $P$ -value over time, ( $P < 0.05$ ) (factorial ANOVA).

between groups were analysed using factorial ANOVA. The level for establishing significant differences was set at  $P < 0.05$ .

### 3. Results

There were 73 subjects recruited for the study. Thirteen subjects were excluded because of premenopausal status (4 cases), hypertension (4 cases), diabetes mellitus (2 cases), physical activity with an expenditure  $> 8373.6$ kJ/day (2 cases), and use of antiobesity medications (1 case). There were 60 subjects enrolled, 42 females and 18 males, all of whom were Khon Kaen University officers. The baseline characteristics of the subjects are shown in Table 1. The average BMI of both groups were classified as grade I obesity. There were no statistical significant differences in food intake, physical activity, or percentage of capsules unused within the same week. The outcome data of the green tea and placebo groups at post-intervention are shown in Table 2. No subjects withdrew from the study and had no subjects reported any significant adverse effects from the experimental protocol.

The reduction of weight corrected for the difference in baseline body weight is shown in Fig. 1.

### 4. Discussion

This study represents the randomized, controlled trial conducted in a free-living condition and consuming food from a hospital-based nutrition unit. We only selected sedentary obese subjects because nearly all obese adults have a sedentary habit. All subjects were blind to the aim of the study. The age restrictions and postmenopausal status were necessary inclusion criteria because basal metabolic rate varies with age, gender, and sex hormone status. No different treatment effects were observed between the males and the females in the study. Therefore, the data for males and females were combined for statistical analysis. No subjects were lost to follow-up because they were accessible in their offices on campus. Thus, this study had no attrition bias. The green tea capsules were analyzed and calculated to have the same dose of EGCG, as in the Dulloo study [4]. The percentage of the unused capsules was the same in both groups and no subject forgot to take capsules more than 20% of

the time. The urine VMA in the green tea group was significantly higher than in the placebo group during the 12th week ( $P < 0.05$ ), indicating that all of the subjects had very good compliance and assuring that the study had no contamination in either group. No statistical difference in physical activity or caloric intake existed between the groups.

In general, weight reduction follows a decrease in energy intake and/or an increase in energy expenditure. In this study, green tea increased energy expenditure by the 8th week of the study; specifically the REE was 372kJ/day higher than at baseline. The increase in REE was approximately one-third of moderate exercise. Dulloo [4] found that green tea extract can increase REE by 329kJ/day, or about one-fourth of moderate exercise. The energy expenditure of our study was slightly higher than reported by Dulloo [4] and may be due to three reasons. First, the method of energy assessment was different. In our study, the open circuit bag technique computerized spirometry was used, while Dulloo used a direct method that determined the effects of green tea in the short term (24h) using a protocol in which the subjects had to withdraw from caffeine-containing foods and beverages for 24h before and until the end of the experiment. On the contrary, the subjects in this study were investigated in a free-living condition. Second, Dulloo used green tea that contained less caffeine than in this study. Third, there was a difference in level of caffeine intake; Caucasians consume much more caffeine than Thais, which leads to a greater tolerance for tea or coffee. Thus, Thais may be more sensitive to green tea than Caucasians. This putative factor is supported by Westerterp-Plantenga et al. [9] that described the relationship of green tea to habitual caffeine intake. The reduction in RQ during treatment with the green tea extract suggests that fat oxidation was higher.

With respect to the satiety score, the green tea group was not statistically different than the placebo group, which differs from the results of animal studies [18,19]. It is possible that the animals received higher dose than were administered in this study. And theoretically, the effects of the method of administration, such as consuming hot tea, may promote a longer gastric emptying time than in capsule form.

There is evidence that green tea polyphenols depress leptin levels, a protein produced by fats which appears to play an important role in how the body manages fat storage through brain signals. As in other studies, by the 12th week of this study [5,7,8], the leptin levels in the green tea group were slightly lower than in the placebo group. This may be because of the action of EGCG or because the body fat percentage in the green tea group was lower than in the placebo group.

The mechanism of weight reduction induced by green tea treatment may be due to the increase in energy expenditure and fat oxidation; however, there is another possible mechanism involved, i.e., suppression of the lipogenic enzyme fatty acid synthase. Lin et al. [16] studied the mechanisms of hypolipidemic and antiobesity effects of tea and tea polyphenols and found that the molecular mechanisms of fatty acid synthase gene suppression by tea polyphenols (EGCG and theaflavins) may incite down-regulation of the EGFR/PI3K/Akt/Sp-1 signal transduction pathways. Yeh et al. [34] studied the suppression of fatty acid synthase in MCF-7 breast cancer cells by tea and tea polyphenols and

found a possible mechanism for their hypolipidemic effects and suggested that tea polyphenols may induce hypolipidemic and antiproliferative effects by suppressing fatty acid synthase. Therefore, antiobesity effect of tea polyphenols could be also observed in the normal (non-obese) people.

The lipolytic activities between ethnic groups are different [27,28]. Also, the components of native foods in warm climates contain more fat than in tropical areas [29,30]. According to the results of green tea function, the consumption of green tea extract elevates both the metabolic rate and the rate of fat oxidation the same in Thais and Caucasians.

There were many factors that influence weight reduction in the treatment of obesity. During the study period, the subjects may modify their behaviors, such as decreasing food intake, increasing physical activities, and forgetting to take the medications. We have eliminated these confounding factors through proper study design by a randomized controlled trial. This study, theoretically, assumed that the confounding factors were similar in both groups and that the differences in the data in both groups during the same week were the true effects of green tea action. There are, however, relevant green tea studies that contradict these results. Diepvens et al. [8] reported the effect of green tea on REE and substrate oxidation during weight loss in overweight females during two phases of weight reduction. In addition, Kovacs et al. [10] reported the effects of green tea on weight maintenance after body weight reduction and found that both results were not significantly different from placebo because of the effect of habitual caffeine intake. However, the increase in energy expenditure in the green tea group had statistical difference ( $P < 0.001$ ) in the 8th week of the study because both groups had caloric intakes lower than 8373.6kJ/day; by the 12th week of the study, both groups had caloric intakes higher than 8373.6kJ/day. Therefore, the weight reduction which occurred during the enrollment-to-8th week of the study may be caused by the effect of green tea and diet control. The evidence supporting this conclusion is the rebound-tendency in body weight during the 8–12th weeks, when the dietary restraint increased in both groups. Based on this, we have assumed that green tea had a greater effect on increasing energy expenditure when the subjects were in a mild negative energy balance in a free living condition than severe negative balance as in the Diepvens et al. [8] and the Kovacs et al. [10] studies. However, the long-term effects of green tea may not have benefit in weight reduction because of the insufficiency of dietary control. And this is the disadvantage of this study that were not studied the long-term effects of green tea.

In conclusion, green tea capsules in a dosage of 100mg/day EGCG can increase energy expenditure and fat oxidation in obese Thai subjects in 12weeks period. The effects of green tea on weight reduction in long-term study are needed.

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