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Research Report

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by Long-term Ingestion of Catechins**

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Life Science

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and Haruo Nakamura<sup>3)</sup>

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**INTRODUCTION**

Lack of exercise due to the development of motorisation and the Westernisation of the Japanese diet have resulted in an increase in the daily fat energy percentage among Japanese people in recent years and this is becoming a serious problem. Studies have shown that individuals with a higher dietary fat intake have a greater body fat percentage<sup>1</sup> and that the accumulation of fat, particularly visceral fat, is closely associated with lifestyle-related diseases such as diabetes mellitus, hyperlipidemia, hypertension and arteriosclerotic disease.<sup>2</sup> Recent work has also shown that not only visceral fat but also abdominal subcutaneous fat plays a role in insulin resistance,<sup>3</sup> indicating that a reduction in abdominal fat is required. Drastic measures to achieve this include improving lifestyle, particularly with regard to diet.

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Green tea, a popular beverage in Japan, contains low-molecular-weight polyphenols, the main constituent of which is flavanol (flavan-3-ol) monomers. These polyphenols, referred to as catechins, include catechin (C), catechin gallate (Cg), galocatechin (GC), galocatechin gallate (GCg), epicatechin (EC), epicatechin gallate (ECg), epigallocatechin (EGC) and epigallocatechin gallate (EGCg). EGC and EGCg usually make up 10-20% of the catechins found in green tea leaves.<sup>4</sup> Catechins have a variety of effects, including antioxidant,<sup>5</sup> antiviral,<sup>6</sup> anti-plaque-formation,<sup>7</sup> antiallergic,<sup>8</sup> anticancer,<sup>9</sup> radioprotective,<sup>10</sup> antihypertensive,<sup>11</sup> and hypoglycemic activity.<sup>12</sup> Animal studies have also shown that catechins affect fat metabolism in that they decrease concentrations of triglycerides<sup>13,14</sup> and total cholesterol,<sup>14</sup> inhibit fat accumulation in the liver,<sup>15,16</sup> inhibit accumulation of body fat<sup>16</sup> and promote energy expenditure.<sup>17</sup> The effect of catechins on fat metabolism in humans is also being investigated. In studies to date, Matsumoto and coworkers found that catechins increase high-density-lipid cholesterol<sup>18</sup> and Dulloo and coworkers reported that catechins promote energy expenditure,<sup>19</sup> suggesting that catechins would also be effective against obesity, which plays a major role in lifestyle-related diseases.

In a recent study in which C57BL/6J mice, a strain used for obesity models, were fed a high-fat diet to induce dietary obesity, the simultaneous ingestion of catechins inhibited increase in body weight, visceral fat and leptin.<sup>20</sup> Ingestion of catechins for 12 weeks also significantly decreased body weight and visceral fat in men with a body mass index (BMI) of 25 kg/m<sup>2</sup> or greater,<sup>21</sup> and intake of catechins at a dose of approximately 550 mg/day for 12 or 20 weeks reduced body fat.<sup>22</sup>

The aim of the present study was to conduct a larger-scale investigation of the body-fat-lowering effects of catechins in humans, including women as subjects.

## **METHODS**

### **1. Test Substance**

Catechins containing C, Cg, GC, GCg, EC, ECg, EGC and EGCg extracted using the method of Hattori and coworkers<sup>23</sup> and assayed as described by Saijo and coworkers<sup>24</sup> were used as the test substance.

The catechins were taken as 340 mL of a green tea-like beverage. Two groups were used in the study, consisting of a control group (126 mg of catechins and 81 mg of caffeine per bottle) and a catechins group (588 mg of catechins and 83 mg of caffeine per bottle) (Table 1).

**Table 1 Catechins and other composition of test beverages**

|                 |                          |           | Control group | Catechin group |
|-----------------|--------------------------|-----------|---------------|----------------|
| Catechins       | Total                    | mg/100 mL | 37.2          | 172.8          |
|                 | Catechin                 | mg/100 mL | 2.3           | 11.6           |
|                 | Catechin gallate         | mg/100 mL | 1.7           | 10.2           |
|                 | Gallocatechin            | mg/100 mL | 9.4           | 39.5           |
|                 | Gallocatechin gallate    | mg/100 mL | 8.0           | 37.2           |
|                 | Epicatechin              | mg/100 mL | 1.4           | 8.1            |
|                 | Epicatechin gallate      | mg/100 mL | 1.6           | 9.0            |
|                 | Epigallocatechin         | mg/100 mL | 5.5           | 23.4           |
|                 | Epigallocatechin gallate | mg/100 mL | 7.4           | 33.8           |
| Caffeine        |                          | mg/100 mL | 23.9          | 24.4           |
| Beverage volume |                          | mL        | 340           | 340            |

- 115 mg / 340 mL  
 - 588 mg / 340 mL

## 2. Subjects and Methods

The study was conducted at Kodama Central Hospital (Kodama-gun, Saitama Prefecture; investigator: Akinori Mashiko), Central Hospital (Shibuya-ku, Tokyo; investigator: Hideyuki Nagata), Hiratsuka Gastroenterological Hospital (Toshima-ku, Tokyo; investigator: Hideo Hiratsuka), Kosei Hospital (Sumida-ku, Tokyo; investigator: Katsuhiko Yamada), Takanashi Clinic (Shinjuku-ku, Tokyo; investigator: Yukie Itagaki) and Isogo Central and Neurosurgical Hospital Health Examination Center (Yokohama, Kanagawa Prefecture; investigator: Takashi Tsuchida) using volunteers as subjects. Informed consent was obtained from the subjects and the study was conducted under the supervision of the investigators and in compliance with the spirit of the Declaration of Helsinki.

The subjects were 43 men aged between 30 and 62 years old (mean BMI: 26.5 kg/m<sup>2</sup>; mean age: 42.1 years) and 37 postmenopausal women aged between 43 and 65 years old (mean BMI: 25.9 kg/m<sup>2</sup>; mean age: 54.8 years) who had a BMI of 24–30 kg/m<sup>2</sup>.

After a 2-week run-in period, the subjects were randomised to the two groups by study site and sex (control group: 23 men and 18 women; catechins group: 20 men and 19 women). The study used double-blinding and was conducted for a total of 26 weeks, consisting of a 12-week test beverage ingestion period (the test period) and a 12-week washout period.

The subjects were required to consume one bottle (340 mL) of the test beverage per day. They were instructed to maintain their normal levels of food consumption and exercise to as great an extent as possible during the study period, and no restrictions were placed on calorie or fat intake. Use of dietary supplements such as psyllium and food fibre that affect energy absorption or drugs that affect fat metabolism was restricted during the study period.

The subjects were required to record in the specified meal diary details about the food they consumed over a 3-day period during 1 week at the start of beverage ingestion (week 0), at completion of beverage ingestion (week 12) and at completion of the washout

period (week 24). They were also asked to record any changes in their lifestyle over a 3-day period each week in a lifestyle diary.

Physical measurements, cardiovascular measurements and interviews were conducted in the run-in period and every 4 weeks from week 0; computed tomography to measure the abdominal fat area was conducted in weeks 0, 12 and 24; and blood chemistry tests, hematology tests and urinalysis were conducted in weeks 0, 8, 12, 20 and 24.

### **3. Meal Diary**

The nutritionist in charge calculated daily energy intake, fat intake and the fat energy percentage from the meal diary and determined the mean for the 3 days.

### **4. Measurement of Physical and Cardiovascular Parameters**

The physical parameters measured were height (run-in period only), body weight, waist circumference, hip circumference and body fat percentage, which was measured by impedance. The cardiovascular parameters measured were systolic blood pressure, diastolic blood pressure and heart rate. BMI was determined from height and bodyweight, the waist/hip ratio (W/H) was determined from the waist and hip circumferences, and body fat mass and lean body mass were calculated from body weight and body fat percentage.

### **5. Evaluation of Abdominal Fat**

The amount of abdominal fat was determined by calculating the total fat area (TFA), visceral fat area (VFA) and subcutaneous fat area (SFA) from CT images of transverse sections at the level of the L4/L5 intervertebral disk using Fat Scan Ver. 2 visceral fat measuring PC software (N2 System Co., Ltd., Osaka, Osaka Prefecture). CT scanning was performed using an X-ray tube voltage of 120 kVp and a tube current of 200 mAs, and the images were processed using a window level of 0 and a window width of 1,000.

### **6. Blood Chemistry and Hematology Tests**

For the blood chemistry and hematology tests, the subjects were not permitted to eat or drink anything except water between 21:00 on

the day before the blood samples were collected and the time of blood collection.

The blood chemistry variables measured were triglycerides (TG), total cholesterol (T-cho), HDL cholesterol (HDL-cho), LDL cholesterol (LDL-cho), non-esterified fatty acids (NEFA), phospholipids (PL), GOT, GPT,  $\gamma$ -GTP, total protein (TP), albumin (Alb), creatinine (Cre), urea nitrogen (BUN), uric acid (UA), lactate dehydrogenase (LDH), alkaline phosphatase (ALP), fasting blood sugar (FBS), total plasminogen activator inhibitor-1 (PAI-1), sodium (Na), potassium (K), calcium (Ca), chloride (Cl), inorganic phosphorus (IP), magnesium (Mg) and iron (Fe). The hematology variables measured were the white blood cell count (WBC), red blood cell count (RBC), haemoglobin (Hb), haematocrit (Ht) and platelet count (PLT).

## **7. Urinalysis**

Urine samples were collected at the same time as the blood samples. Glucose, protein, urobilinogen and ketone bodies were determined by dipstick test, and the sediment was examined by microscopy if the urine was positive for protein.

## **8. Analysis of Data**

Energy intake, fat intake and the fat energy percentage calculated from the meal diary are shown as the mean  $\pm$  standard error for the measured values. The significance of differences between the groups was assessed by repeated measures analysis of variance using the numerical values from weeks 0 to 12 (the test period) and by performing unpaired *t*-tests at each measurement time. Within-group comparisons to assess for significant differences in the measured values relative to week 0 were done by paired *t*-test.

The physical parameters and amount of abdominal fat are shown as the mean  $\pm$  standard error for the measured values and change from week 0 ( $\Delta$  value). Significant differences in the measured values between the groups were assessed by repeated measures analysis of variance using the numerical values from weeks 0 to 12 (the test period) and by performing unpaired *t*-tests at each measurement time. Significant differences in change between the groups were assessed by repeated measures analysis of variance using the

numerical values from week 4 to week 12 (the test period) and by performing unpaired *t*-tests at each measurement time. Within-group comparisons to assess significant differences in the measured values relative to week 0 were done by paired *t*-test.

The measured values for the cardiovascular, blood chemistry and hematology variables are shown as the mean  $\pm$  standard error. Significant differences in the measured values between the groups were assessed by repeated measures analysis of variance using the numerical values from week 0 to week 12 (the test period) and by unpaired *t*-test at each measurement time. Within-group comparisons to assess significant differences in the measured values relative to week 0 were done by paired *t*-test.

All of the statistical analyses were done with StatView\_for Windows Version 4.58 (SAS Institute Inc., Cary, USA).

## RESULTS

### 1. Diet During Study

Energy intake, fat intake and the fat energy percentage are shown in Table 2. Fat intake and the fat energy percentage in the control group were significantly lower in week 12, but there were no significant differences between the groups for any of the variables.

Table 2 Changes of daily food intake<sup>a</sup>

|                       |                   | Test period |                | Wash out period             |                |
|-----------------------|-------------------|-------------|----------------|-----------------------------|----------------|
|                       |                   | 0wk         | 12wks          | 24wks                       |                |
| Energy intake         | Control (n = 41)  | kcal        | 1,728 $\pm$ 62 | 1,687 $\pm$ 47              | 1,695 $\pm$ 37 |
|                       | Catechin (n = 39) | kcal        | 1,738 $\pm$ 75 | 1,664 $\pm$ 48              | 1,686 $\pm$ 49 |
| Fat intake            | Control (n = 41)  | g           | 51.4 $\pm$ 2.3 | 46.1 $\pm$ 1.8 <sup>b</sup> | 47.8 $\pm$ 1.8 |
|                       | Catechin (n = 39) | g           | 50.9 $\pm$ 3.6 | 45.4 $\pm$ 2.1              | 47.1 $\pm$ 1.7 |
| Percent of fat energy | Control (n = 41)  | %           | 26.5 $\pm$ 0.7 | 24.4 $\pm$ 0.6 <sup>*</sup> | 25.2 $\pm$ 0.6 |
|                       | Catechin (n = 39) | %           | 25.7 $\pm$ 0.9 | 24.2 $\pm$ 0.7              | 25.0 $\pm$ 0.6 |

a : Values are mean  $\pm$  SEM.

b : Significantly different from the 0wk value by *t*-test (paired. \* ; *p* < 0.05).

### 2. Change in Measured Values for Physical Parameters



There were no between-group differences in any of the physical parameters in week 0 (Table 3).

Change in body weight differed significantly between the groups in weeks 4 and 12 (test period) and was significantly lower in the catechins group than in the control group throughout the test period. Body weight was significantly lower in the catechins group in weeks 4, 8 and 12 (test period) and weeks 16 and 20 (washout period) (Table 3). Change in the BMI differed significantly between the groups in week 12 (test period) and was significantly lower in the catechins group than in the control group throughout the test period. The BMI was significantly lower in the control group in week 20 (washout period) and in the catechins group in weeks 4, 8 and 12 (test period) and weeks 16 and 20 (washout period) (Table 3). Change in the body fat percentage was significantly lower in the catechins group than in the control group in week 12 (test period). The body fat percentage was significantly lower in the catechins group in weeks 8 and 12 (test period) (Table 3). The waist circumference was significantly lower in the control group in weeks 4, 8 and 12 (test period) and weeks 16, 20 and 24 (washout period) and in the catechins group in weeks 4, 8 and 12 (test period) and week 16 (washout period), but there were no significant differences between the groups (Table 3). Change in hip circumference differed significantly between the groups in week 12 (test period) and was significantly lower in the catechins group than in the control group throughout the test period. The hip circumference was significantly lower in the catechins group in weeks 4, 8 and 12 (test period) and weeks 16 and 20 (washout period) (Table 3). Change in the W/H was significantly higher in the catechins group than in the control group in weeks 16, 20 and 24 (washout period). The W/H was significantly lower in the control group in weeks 8 and 12 (test period) and weeks 16, 20 and 24 (washout period) and in the catechins group in week 12 (test period) (Table 3). Change in body fat mass differed significantly between the groups in week 12 (test period) and was significantly lower in the catechins group than in the control group throughout the test period. Body fat mass was significantly lower in the catechins group in weeks 4, 8 and 12 (test period) (Table 3). Lean body mass was significantly lower in the catechins group in weeks 20 and 24 (washout period), but there were no significant differences between the groups (Table 3).

There was no rebound effect as a result of decreased catechin ingestion, since there was no significant increase in the measured values in the washout period relative to week 0 for any of the variables for which significant between-group differences were seen previously.

### **3. Change in Abdominal Fat Area Determined by CT at the Naval Level**

There were no between-group differences in any of the variables in week 0 (Table 3).

Change in the TFA in week 12 (test period) and week 24 (washout period) was significantly lower in the catechins group than in the control group. The TFA was significantly lower in the catechins group in week 12 (test period) and week 24 (washout period) (Table 3). Change in the VFA and SFA was significantly lower in the catechins group than in the control group in week 12 (test period). The VFA and SFA were significantly lower in the catechins group in week 12 (test period) and week 24 (washout period) (Table 3).

There was no rebound effect as a result of decreased catechin ingestion, since there was no significant increase in the measured values in the washout period relative to week 0 for any of the variables for which significant between-group differences were seen previously.

### **4. Change in Measured Values for Cardiovascular Parameters**

There were no between-group differences in any of the variables in week 0 (Table 3).

There was no change in systolic or diastolic blood pressure in either of the groups (Table 3). Heart rate was significantly higher in the control group in week 24 (test period) and significantly lower in the catechins group in week 4 (test period), but there were no significant differences between the groups (Table 3).

Table 3 Effects of catechin

|                  |                   |                     | Test period    |                             |                            |
|------------------|-------------------|---------------------|----------------|-----------------------------|----------------------------|
|                  |                   |                     | 0 wk           | 4 wks                       | 8 wks                      |
| Weight           | Control (n = 41)  | kg                  | 70.36 ± 2.00   | 70.40 ± 2.08                | 70.01 ± 2.06               |
|                  |                   | Δ kg                |                | 0.04 ± 0.21 <sup>b</sup>    | -0.35 ± 0.31               |
|                  | Catechin (n = 39) | kg                  | 70.68 ± 1.85   | 70.14 ± 1.87 <sup>a,i</sup> | 69.63 ± 1.90 <sup>a</sup>  |
|                  |                   | Δ kg                |                | -0.54 ± 0.20 <sup>a</sup>   | -1.06 ± 0.25               |
| BMI              | Control (n = 41)  | kg/m <sup>2</sup>   | 26.06 ± 0.31   | 26.06 ± 0.34                | 25.93 ± 0.35               |
|                  |                   | Δ kg/m <sup>2</sup> |                | 0.00 ± 0.07                 | -0.13 ± 0.10               |
|                  | Catechin (n = 39) | kg/m <sup>2</sup>   | 26.43 ± 0.37   | 26.23 ± 0.38 <sup>a</sup>   | 26.02 ± 0.39 <sup>a</sup>  |
|                  |                   | Δ kg/m <sup>2</sup> |                | -0.21 ± 0.08                | -0.41 ± 0.10               |
| Body fat ratio   | Control (n = 41)  | %                   | 28.09 ± 0.82   | 27.98 ± 0.83                | 27.78 ± 0.91               |
|                  |                   | Δ %                 |                | -0.11 ± 0.24                | -0.31 ± 0.37               |
|                  | Catechin (n = 39) | %                   | 28.98 ± 0.98   | 28.69 ± 0.99                | 28.33 ± 0.96 <sup>a</sup>  |
|                  |                   | Δ %                 |                | -0.28 ± 0.18                | -0.65 ± 0.26               |
| Waist            | Control (n = 41)  | cm                  | 86.18 ± 1.60   | 85.62 ± 1.57 <sup>a</sup>   | 84.90 ± 1.50 <sup>a</sup>  |
|                  |                   | Δ cm                |                | -0.57 ± 0.24                | -1.29 ± 0.47               |
|                  | Catechin (n = 39) | cm                  | 85.19 ± 1.46   | 84.72 ± 1.44 <sup>a</sup>   | 84.09 ± 1.42 <sup>a</sup>  |
|                  |                   | Δ cm                |                | -0.47 ± 0.19                | -1.11 ± 0.31               |
| Hip              | Control (n = 41)  | cm                  | 97.62 ± 1.15   | 97.66 ± 1.17                | 97.44 ± 1.18               |
|                  |                   | Δ cm                |                | 0.04 ± 0.27                 | -0.18 ± 0.33               |
|                  | Catechin (n = 39) | cm                  | 98.39 ± 1.01   | 97.86 ± 1.01 <sup>a</sup>   | 97.47 ± 1.06 <sup>a</sup>  |
|                  |                   | Δ cm                |                | -0.53 ± 0.15                | -0.92 ± 0.23               |
| W/H <sup>c</sup> | Control (n = 41)  |                     | 0.882 ± 0.011  | 0.876 ± 0.011               | 0.871 ± 0.011 <sup>a</sup> |
|                  |                   | Δ                   |                | -0.006 ± 0.003              | -0.011 ± 0.004             |
|                  | Catechin (n = 39) |                     | 0.866 ± 0.012  | 0.866 ± 0.012               | 0.863 ± 0.012              |
|                  |                   | Δ                   |                | 0.000 ± 0.002               | -0.003 ± 0.002             |
| Body fat mass    | Control (n = 41)  | kg                  | 19.59 ± 0.74   | 19.56 ± 0.60                | 19.31 ± 0.82               |
|                  |                   | Δ kg                |                | -0.03 ± 0.23                | -0.29 ± 0.33               |
|                  | Catechin (n = 39) | kg                  | 20.49 ± 0.93   | 20.14 ± 0.94 <sup>a</sup>   | 19.75 ± 0.94 <sup>a</sup>  |
|                  |                   | Δ kg                |                | -0.35 ± 0.15                | -0.74 ± 0.22               |
| Lean body mass   | Control (n = 41)  | kg                  | 50.77 ± 1.65   | 50.83 ± 1.66                | 50.70 ± 1.67               |
|                  |                   | Δ kg                |                | 0.06 ± 0.17                 | -0.06 ± 0.27               |
|                  | Catechin (n = 39) | kg                  | 50.19 ± 1.47   | 50.00 ± 1.48                | 49.87 ± 1.48               |
|                  |                   | Δ kg                |                | -0.20 ± 0.16                | -0.32 ± 0.21               |
| TFA <sup>d</sup> | Control (n = 41)  | cm <sup>2</sup>     | 313.86 ± 15.97 |                             |                            |
|                  |                   | Δ cm <sup>2</sup>   |                |                             |                            |
|                  | Catechin (n = 39) | cm <sup>2</sup>     | 327.23 ± 15.92 |                             |                            |
|                  |                   | Δ cm <sup>2</sup>   |                |                             |                            |
| VFA <sup>e</sup> | Control (n = 41)  | cm <sup>2</sup>     | 109.89 ± 7.22  |                             |                            |
|                  |                   | Δ cm <sup>2</sup>   |                |                             |                            |
|                  | Catechin (n = 39) | cm <sup>2</sup>     | 114.05 ± 7.53  |                             |                            |
|                  |                   | Δ cm <sup>2</sup>   |                |                             |                            |
| SFA <sup>f</sup> | Control (n = 41)  | cm <sup>2</sup>     | 203.96 ± 11.29 |                             |                            |
|                  |                   | Δ cm <sup>2</sup>   |                |                             |                            |
|                  | Catechin (n = 39) | cm <sup>2</sup>     | 213.18 ± 11.30 |                             |                            |
|                  |                   | Δ cm <sup>2</sup>   |                |                             |                            |
| SBP <sup>g</sup> | Control (n = 41)  | mmHG                | 132.93 ± 2.60  | 131.71 ± 2.20               | 130.10 ± 2.34              |
|                  |                   |                     |                |                             |                            |
|                  | Catechin (n = 39) | mmHG                | 132.85 ± 2.99  | 132.41 ± 2.56               | 131.85 ± 2.46              |
|                  |                   |                     |                |                             |                            |
| DBP <sup>g</sup> | Control (n = 41)  | mmHG                | 82.51 ± 1.52   | 81.80 ± 1.31                | 81.24 ± 1.66               |
|                  |                   |                     |                |                             |                            |
|                  | Catechin (n = 39) | mmHG                | 79.62 ± 1.76   | 80.13 ± 1.56                | 81.44 ± 1.74               |
|                  |                   |                     |                |                             |                            |
| Pulse            | Control (n = 41)  | beat/min            | 73.66 ± 1.01   | 73.15 ± 1.09                | 74.34 ± 0.91               |
|                  |                   |                     |                |                             |                            |
|                  | Catechin (n = 39) | beat/min            | 76.36 ± 1.33   | 75.26 ± 1.27 <sup>a</sup>   | 75.56 ± 1.32               |
|                  |                   |                     |                |                             |                            |

a : Values are mean ± SEM., b : Change from 0wk., c : Waist to hip circumference ratio., d : Total fat Diastolic blood pressure, i : Significantly different from the 0 wk value by t-test (paired. \* ; p < 0.05, \*\* ; p < 0.01).

administration on body indices\*

|        | Wash out period  |                |                 |                  | P value of ANOVA<br>(Test period) |
|--------|------------------|----------------|-----------------|------------------|-----------------------------------|
|        | 12 wks           | 16 wks         | 20 wks          | 24 wks           |                                   |
|        | 69.92 ± 2.10     | 69.79 ± 2.13   | 69.76 ± 2.09    | 69.95 ± 2.14     |                                   |
|        | -0.44 ± 0.37     | -0.57 ± 0.36   | -0.60 ± 0.31    | -0.41 ± 0.38     |                                   |
| 2.44 = | 68.99 ± 1.88**   | 69.78 ± 1.87** | 70.15 ± 1.87*   | 70.45 ± 1.86     | 0.9117                            |
|        | -1.69 ± 0.28**   | -0.90 ± 0.26   | -0.53 ± 0.26    | -0.23 ± 0.27     | 0.0226                            |
|        | 25.83 ± 0.36     | 25.82 ± 0.37   | 25.82 ± 0.36*   | 25.88 ± 0.37     |                                   |
|        | -0.17 ± 0.12     | -0.23 ± 0.12   | -0.23 ± 0.11    | -0.17 ± 0.12     |                                   |
| 2.56 = | 25.78 ± 0.37**   | 26.08 ± 0.37** | 26.22 ± 0.37*   | 26.34 ± 0.38     | 0.7946                            |
|        | -0.66 ± 0.11**   | -0.35 ± 0.10   | -0.21 ± 0.10    | -0.09 ± 0.11     | 0.0137                            |
|        | 27.96 ± 0.92     | 28.02 ± 1.03   | 27.83 ± 1.00    | 27.86 ± 0.97     |                                   |
|        | -0.13 ± 0.40     | -0.07 ± 0.52   | -0.26 ± 0.50    | -0.23 ± 0.49     |                                   |
|        | 27.47 ± 1.00**   | 28.76 ± 0.98   | 29.43 ± 0.98    | 29.56 ± 0.98     | 0.7485                            |
|        | -1.51 ± 0.32**   | -0.22 ± 0.41   | 0.45 ± 0.39     | 0.58 ± 0.31      | 0.1009                            |
|        | 84.85 ± 1.65**   | 84.68 ± 1.59*  | 84.85 ± 1.58*   | 84.87 ± 1.58*    |                                   |
|        | -1.33 ± 0.62     | -1.50 ± 0.66   | -1.33 ± 0.59    | -1.31 ± 0.61     |                                   |
|        | 83.33 ± 1.44**   | 84.22 ± 1.43** | 84.62 ± 1.46    | 84.87 ± 1.46     | 0.6213                            |
|        | -1.87 ± 0.30     | -0.98 ± 0.31   | -0.57 ± 0.29    | -0.32 ± 0.29     | 0.8593                            |
|        | 97.51 ± 1.22     | 97.60 ± 1.21   | 97.74 ± 1.29    | 97.54 ± 1.21     |                                   |
|        | -0.11 ± 0.41     | -0.02 ± 0.44   | 0.12 ± 0.47     | -0.08 ± 0.43     |                                   |
|        | 96.86 ± 1.06**   | 97.10 ± 1.00** | 97.81 ± 1.05*   | 98.04 ± 1.05     | 0.9559                            |
|        | -1.53 ± 0.27**   | -1.29 ± 0.31   | -0.58 ± 0.24    | -0.35 ± 0.24     | 0.0126                            |
|        | 0.869 ± 0.011*   | 0.867 ± 0.011* | 0.868 ± 0.011*  | 0.869 ± 0.011*   |                                   |
|        | -0.013 ± 0.005   | -0.015 ± 0.006 | -0.014 ± 0.005  | -0.013 ± 0.005   |                                   |
|        | 0.860 ± 0.012*   | 0.867 ± 0.012  | 0.865 ± 0.012   | 0.866 ± 0.012    | 0.4714                            |
|        | -0.005 ± 0.002   | 0.001 ± 0.003* | -0.001 ± 0.002* | 0.000 ± 0.002*   | 0.1164                            |
|        | 19.42 ± 0.85     | 19.35 ± 0.87   | 19.21 ± 0.84    | 19.30 ± 0.85     |                                   |
|        | -0.17 ± 0.37     | -0.25 ± 0.43   | -0.39 ± 0.44    | -0.29 ± 0.43     |                                   |
| 2.74 = | 18.95 ± 0.93**   | 20.04 ± 0.91   | 20.51 ± 0.91    | 20.82 ± 0.93     | 0.7637                            |
|        | -1.54 ± 0.29**   | -0.45 ± 0.32   | 0.12 ± 0.31     | 0.33 ± 0.27      | 0.0468                            |
|        | 50.50 ± 1.68     | 50.45 ± 1.82   | 50.55 ± 1.79    | 50.65 ± 1.80     |                                   |
|        | -0.27 ± 0.25     | -0.32 ± 0.48   | -0.22 ± 0.45    | -0.12 ± 0.47     |                                   |
|        | 50.04 ± 1.52     | 49.74 ± 1.52   | 49.54 ± 1.52**  | 49.63 ± 1.48**   | 0.7634                            |
|        | -0.15 ± 0.23     | -0.45 ± 0.28   | -0.65 ± 0.24    | -0.56 ± 0.17     | 0.6197                            |
|        | 311.99 ± 16.62   |                |                 | 310.82 ± 17.47   |                                   |
|        | -1.86 ± 5.11     |                |                 | -3.03 ± 6.52     |                                   |
|        | 300.86 ± 16.04** |                |                 | 302.14 ± 15.02** |                                   |
|        | -26.37 ± 3.81**  |                |                 | -25.09 ± 6.59*   |                                   |
|        | 110.18 ± 7.20    |                |                 | 107.87 ± 7.34    |                                   |
|        | 0.29 ± 2.50      |                |                 | -2.02 ± 2.88     |                                   |
|        | 105.34 ± 7.42**  |                |                 | 103.45 ± 6.80**  |                                   |
|        | -8.71 ± 2.48*    |                |                 | -10.61 ± 3.61    |                                   |
|        | 201.81 ± 11.72   |                |                 | 202.96 ± 12.63   |                                   |
|        | -2.15 ± 3.76     |                |                 | -1.01 ± 4.93     |                                   |
|        | 195.51 ± 10.93** |                |                 | 198.70 ± 11.04*  |                                   |
|        | -17.66 ± 4.03**  |                |                 | -14.48 ± 5.36    |                                   |
|        | 132.15 ± 2.42    | 131.54 ± 2.23  | 133.46 ± 2.03   | 129.20 ± 2.20    |                                   |
|        | 130.85 ± 2.39    | 131.74 ± 1.95  | 132.59 ± 2.11   | 131.87 ± 2.33    | 0.9350                            |
|        | 80.56 ± 1.61     | 80.90 ± 1.44   | 81.27 ± 1.29    | 80.17 ± 1.62     |                                   |
|        | 78.49 ± 1.44     | 80.62 ± 1.47   | 80.95 ± 1.44    | 80.56 ± 1.51     | 0.4276                            |
|        | 74.85 ± 1.24     | 74.85 ± 1.12   | 75.02 ± 0.97    | 76.44 ± 1.12*    |                                   |
|        | 75.46 ± 1.24     | 75.79 ± 1.26   | 76.28 ± 1.03    | 76.03 ± 1.17     | 0.2695                            |

area, e : Visceral fat area, f : Subcutaneous fat area, g : Systolic blood pressure, h :  
 \*\* : p < 0.01. j : Significantly different from control group by t-test (unpaired. \* ; p <

Table 4 Effects of catechin administration on blood parameters<sup>a</sup>

|         |                   |                       | Test period               |                             |                            | Wash out period            |                             | P value of ANOVA<br>(Test period) |
|---------|-------------------|-----------------------|---------------------------|-----------------------------|----------------------------|----------------------------|-----------------------------|-----------------------------------|
|         |                   |                       | 0 wk                      | 8 wks                       | 12 wks                     | 20 wks                     | 24 wks                      |                                   |
| TG      | Control (n = 41)  | mg/dL                 | 129.7 ± 9.5               | 125.5 ± 9.7                 | 130.7 ± 11.4               | 133.3 ± 9.8                | 132.8 ± 8.8                 | 0.0407                            |
|         | Catechin (n = 39) | mg/dL                 | 157.4 ± 16.2              | 160.1 ± 12.5 <sup>b</sup>   | 168.9 ± 16.1               | 162.4 ± 14.3               | 154.9 ± 16.3                |                                   |
| T-cho   | Control (n = 41)  | mg/dL                 | 212.3 ± 5.7               | 213.0 ± 5.8                 | 211.7 ± 6.2                | 216.2 ± 5.3                | 216.0 ± 5.3                 | 0.8316                            |
|         | Catechin (n = 39) | mg/dL                 | 213.7 ± 6.2               | 210.4 ± 6.1 <sup>**</sup>   | 212.9 ± 6.1                | 214.7 ± 6.4                | 212.2 ± 6.5                 |                                   |
| HDL-cho | Control (n = 41)  | mg/dL                 | 51.4 ± 2.0                | 53.6 ± 2.0 <sup>**</sup>    | 54.5 ± 2.0 <sup>*</sup>    | 56.2 ± 1.9 <sup>**</sup>   | 54.1 ± 1.9 <sup>*</sup>     | 0.9932                            |
|         | Catechin (n = 39) | mg/dL                 | 52.2 ± 2.7                | 53.0 ± 2.6                  | 54.4 ± 2.2                 | 54.7 ± 2.4                 | 54.2 ± 2.5                  |                                   |
| LDL-cho | Control (n = 41)  | mg/dL                 | 134.2 ± 6.0               | 134.7 ± 6.3                 | 133.7 ± 6.3                | 138.1 ± 6.3                | 134.0 ± 5.4                 | 0.5415                            |
|         | Catechin (n = 39) | mg/dL                 | 131.2 ± 6.7               | 128.0 ± 7.3                 | 127.1 ± 7.1                | 131.7 ± 7.2                | 130.9 ± 6.3                 |                                   |
| NEFA    | Control (n = 41)  | mEq/L                 | 0.610 ± 0.037             | 0.534 ± 0.039               | 0.557 ± 0.035              | 0.553 ± 0.043              | 0.530 ± 0.039               | 0.3296                            |
|         | Catechin (n = 39) | mEq/L                 | 0.676 ± 0.075             | 0.591 ± 0.048               | 0.591 ± 0.045              | 0.644 ± 0.050              | 0.668 ± 0.055 <sup>*</sup>  |                                   |
| PL      | Control (n = 41)  | mg/dL                 | 223.8 ± 4.8               | 223.8 ± 4.6                 | 221.5 ± 5.4                | 229.4 ± 4.6                | 229.7 ± 5.5                 | 0.4875                            |
|         | Catechin (n = 39) | mg/dL                 | 231.9 ± 7.6               | 225.5 ± 6.6                 | 228.1 ± 6.2                | 229.8 ± 6.5                | 228.3 ± 6.8                 |                                   |
| GOT     | Control (n = 41)  | IU/L                  | 29.8 ± 4.1                | 27.9 ± 3.1                  | 26.7 ± 2.7                 | 26.3 ± 2.8                 | 25.6 ± 2.5                  | 0.4724                            |
|         | Catechin (n = 39) | IU/L                  | 26.4 ± 1.9                | 25.8 ± 1.5                  | 24.5 ± 1.7                 | 25.3 ± 1.4                 | 24.8 ± 1.4                  |                                   |
| GPT     | Control (n = 41)  | IU/L                  | 39.5 ± 6.1                | 35.0 ± 4.7                  | 34.4 ± 4.2                 | 34.0 ± 4.3                 | 33.4 ± 4.2                  | 0.9502                            |
|         | Catechin (n = 39) | IU/L                  | 38.3 ± 4.8                | 36.3 ± 4.2                  | 35.5 ± 3.9                 | 36.1 ± 3.9                 | 34.8 ± 3.5                  |                                   |
| γ-GTP   | Control (n = 41)  | IU/L                  | 46.0 ± 8.5                | 38.5 ± 5.8                  | 37.7 ± 5.2                 | 36.8 ± 5.2                 | 33.8 ± 5.3 <sup>*</sup>     | 0.3603                            |
|         | Catechin (n = 39) | IU/L                  | 34.5 ± 4.3                | 33.7 ± 4.7                  | 32.5 ± 5.0                 | 34.5 ± 6.3                 | 32.1 ± 5.7                  |                                   |
| TP      | Control (n = 41)  | g/dL                  | 7.40 ± 0.07               | 7.43 ± 0.08                 | 7.26 ± 0.07 <sup>*</sup>   | 7.34 ± 0.07                | 7.36 ± 0.07                 | 0.3022                            |
|         | Catechin (n = 39) | g/dL                  | 7.47 ± 0.10               | 7.46 ± 0.07                 | 7.43 ± 0.06                | 7.44 ± 0.07                | 7.46 ± 0.07                 |                                   |
| Alb     | Control (n = 41)  | g/dL                  | 4.46 ± 0.07               | 4.45 ± 0.06                 | 4.39 ± 0.06                | 4.54 ± 0.06 <sup>*</sup>   | 4.48 ± 0.06                 | 0.1161                            |
|         | Catechin (n = 39) | g/dL                  | 4.55 ± 0.06               | 4.55 ± 0.05                 | 4.56 ± 0.05 <sup>*</sup>   | 4.57 ± 0.05                | 4.59 ± 0.05                 |                                   |
| Cre     | Control (n = 41)  | mg/dL                 | 0.795 ± 0.030             | 0.747 ± 0.030 <sup>**</sup> | 0.776 ± 0.032              | 0.731 ± 0.031 <sup>*</sup> | 0.770 ± 0.029               | 0.6126                            |
|         | Catechin (n = 39) | mg/dL                 | 0.779 ± 0.029             | 0.808 ± 0.030               | 0.793 ± 0.028              | 0.810 ± 0.030 <sup>*</sup> | 0.815 ± 0.030 <sup>**</sup> |                                   |
| BUN     | Control (n = 41)  | mg/dL                 | 13.2 ± 0.4                | 12.9 ± 0.5                  | 13.2 ± 0.5                 | 13.7 ± 0.4                 | 14.0 ± 0.5                  | 0.1437                            |
|         | Catechin (n = 39) | mg/dL                 | 13.7 ± 0.5                | 13.8 ± 0.4                  | 14.4 ± 0.5                 | 14.4 ± 0.5                 | 14.3 ± 0.5                  |                                   |
| UA      | Control (n = 41)  | mg/dL                 | 5.53 ± 0.25               | 5.23 ± 0.22 <sup>**</sup>   | 5.37 ± 0.23                | 5.22 ± 0.20 <sup>*</sup>   | 5.34 ± 0.21                 | 0.7540                            |
|         | Catechin (n = 39) | mg/dL                 | 5.25 ± 0.22               | 5.24 ± 0.25                 | 5.34 ± 0.23                | 5.40 ± 0.23                | 5.43 ± 0.23                 |                                   |
| LDH     | Control (n = 41)  | IU/L                  | 304.2 ± 19.4              | 294.2 ± 18.7                | 290.0 ± 17.6 <sup>*</sup>  | 292.3 ± 18.6               | 284.5 ± 17.4 <sup>**</sup>  | 0.5482                            |
|         | Catechin (n = 39) | IU/L                  | 281.4 ± 18.0              | 290.2 ± 19.7                | 270.9 ± 16.5               | 273.4 ± 15.9               | 276.3 ± 16.6                |                                   |
| ALP     | Control (n = 41)  | IU/L                  | 139.7 ± 16.9              | 130.9 ± 16.4 <sup>*</sup>   | 178.9 ± 16.9 <sup>**</sup> | 181.0 ± 17.0               | 179.0 ± 16.5 <sup>*</sup>   | 0.7446                            |
|         | Catechin (n = 39) | IU/L                  | 178.8 ± 12.7              | 177.8 ± 12.1                | 172.5 ± 12.0               | 174.3 ± 11.4               | 172.3 ± 12.4                |                                   |
| FBS     | Control (n = 41)  | mg/dL                 | 94.0 ± 2.0                | 97.9 ± 2.7                  | 95.9 ± 2.8                 | 96.0 ± 2.8                 | 96.3 ± 2.2                  | 0.0878                            |
|         | Catechin (n = 39) | mg/dL                 | 107.5 ± 5.7 <sup>ab</sup> | 104.5 ± 5.8                 | 101.0 ± 3.9                | 105.2 ± 4.2                | 98.5 ± 2.6                  |                                   |
| PAI-1   | Control (n = 41)  | ng/dL                 | 43.2 ± 4.5                | 47.9 ± 5.2                  | 35.1 ± 3.9 <sup>*</sup>    | 43.0 ± 3.6                 | 39.0 ± 4.5                  | 0.5106                            |
|         | Catechin (n = 39) | ng/dL                 | 35.7 ± 3.8                | 41.3 ± 4.2                  | 39.6 ± 0.0                 | 40.4 ± 4.4                 | 40.7 ± 5.4                  |                                   |
| Na      | Control (n = 41)  | mEq/L                 | 142.4 ± 0.4               | 141.9 ± 0.6                 | 142.0 ± 0.3                | 142.5 ± 0.4                | 142.9 ± 0.3                 | 0.8323                            |
|         | Catechin (n = 39) | mEq/L                 | 142.0 ± 0.4               | 142.2 ± 0.4                 | 142.5 ± 0.4                | 141.9 ± 0.4                | 142.5 ± 0.4                 |                                   |
| K       | Control (n = 41)  | mEq/L                 | 4.22 ± 0.06               | 4.30 ± 0.05                 | 4.27 ± 0.06                | 4.33 ± 0.05                | 4.35 ± 0.06 <sup>**</sup>   | 0.9992                            |
|         | Catechin (n = 39) | mEq/L                 | 4.07 ± 0.05               | 4.35 ± 0.06 <sup>**</sup>   | 4.37 ± 0.06 <sup>**</sup>  | 4.37 ± 0.05 <sup>**</sup>  | 4.32 ± 0.05 <sup>**</sup>   |                                   |
| Ca      | Control (n = 41)  | mEq/L                 | 6.24 ± 0.34               | 6.24 ± 0.35                 | 6.11 ± 0.35 <sup>**</sup>  | 6.13 ± 0.34 <sup>**</sup>  | 6.13 ± 0.35 <sup>**</sup>   | 0.3897                            |
|         | Catechin (n = 39) | mEq/L                 | 6.64 ± 0.38               | 6.63 ± 0.39                 | 6.67 ± 0.40 <sup>**</sup>  | 6.55 ± 0.38 <sup>**</sup>  | 6.53 ± 0.38 <sup>**</sup>   |                                   |
| Cl      | Control (n = 41)  | mEq/L                 | 103.9 ± 0.5               | 103.5 ± 0.5                 | 103.5 ± 0.4                | 104.2 ± 0.5                | 104.4 ± 0.5                 | 0.4542                            |
|         | Catechin (n = 39) | mEq/L                 | 102.7 ± 0.5               | 103.0 ± 0.4                 | 103.9 ± 0.4 <sup>**</sup>  | 103.8 ± 0.5 <sup>*</sup>   | 103.8 ± 0.5 <sup>**</sup>   |                                   |
| IP      | Control (n = 41)  | mg/dL                 | 3.35 ± 0.08               | 3.40 ± 0.09                 | 3.41 ± 0.07                | 3.45 ± 0.08                | 3.45 ± 0.08                 | 0.5827                            |
|         | Catechin (n = 39) | mg/dL                 | 3.49 ± 0.11               | 3.37 ± 0.08                 | 3.46 ± 0.08                | 3.47 ± 0.07                | 3.45 ± 0.08                 |                                   |
| Mg      | Control (n = 41)  | mg/dL                 | 2.21 ± 0.03               | 2.18 ± 0.03                 | 2.19 ± 0.03                | 2.20 ± 0.03                | 2.17 ± 0.03                 | 0.4992                            |
|         | Catechin (n = 39) | mg/dL                 | 2.14 ± 0.03               | 2.21 ± 0.03 <sup>*</sup>    | 2.16 ± 0.03                | 2.15 ± 0.02                | 2.20 ± 0.02                 |                                   |
| Fe      | Control (n = 41)  | μg/dL                 | 98.5 ± 5.4                | 114.6 ± 6.2 <sup>**</sup>   | 105.8 ± 5.4                | 98.6 ± 4.6                 | 108.2 ± 6.0                 | 0.5882                            |
|         | Catechin (n = 39) | μg/dL                 | 104.2 ± 5.5               | 106.5 ± 5.2                 | 98.2 ± 4.3                 | 98.6 ± 3.7                 | 104.7 ± 5.0                 |                                   |
| WBC     | Control (n = 41)  | /μL                   | 6,260 ± 210               | 6,335 ± 283                 | 6,147 ± 240                | 6,018 ± 236                | 6,085 ± 225                 | 0.3497                            |
|         | Catechin (n = 39) | /μL                   | 6,539 ± 269               | 6,643 ± 309                 | 6,522 ± 279                | 6,469 ± 263                | 6,101 ± 213 <sup>*</sup>    |                                   |
| RBC     | Control (n = 41)  | × 10 <sup>4</sup> /μL | 478.4 ± 8.5               | 478.2 ± 8.0                 | 466.2 ± 6.9 <sup>**</sup>  | 468.9 ± 6.8                | 469.7 ± 6.8                 | 0.8590                            |
|         | Catechin (n = 39) | × 10 <sup>4</sup> /μL | 476.5 ± 7.8               | 472.6 ± 7.8                 | 468.4 ± 7.1 <sup>*</sup>   | 471.3 ± 7.3                | 469.8 ± 6.7                 |                                   |
| Hb      | Control (n = 41)  | g/dL                  | 14.8 ± 0.3                | 14.7 ± 0.3                  | 14.6 ± 0.2                 | 14.7 ± 0.2                 | 14.7 ± 0.2                  | 0.8956                            |
|         | Catechin (n = 39) | g/dL                  | 14.9 ± 0.3                | 14.7 ± 0.2                  | 14.7 ± 0.2                 | 14.7 ± 0.2                 | 14.7 ± 0.2                  |                                   |
| Ht      | Control (n = 41)  | %                     | 43.8 ± 0.8                | 44.1 ± 0.7                  | 43.4 ± 0.7                 | 43.8 ± 0.6                 | 43.6 ± 0.6                  | 0.8494                            |
|         | Catechin (n = 39) | %                     | 43.9 ± 0.6                | 44.0 ± 0.6                  | 44.0 ± 0.6                 | 44.2 ± 0.6                 | 43.8 ± 0.6                  |                                   |
| PLT     | Control (n = 41)  | × 10 <sup>4</sup> /μL | 24.9 ± 0.9                | 24.7 ± 0.9                  | 24.0 ± 0.9                 | 24.3 ± 0.8                 | 24.0 ± 0.8                  | 0.9461                            |
|         | Catechin (n = 39) | × 10 <sup>4</sup> /μL | 24.7 ± 0.9                | 24.6 ± 1.0                  | 24.5 ± 0.9                 | 23.9 ± 0.9                 | 24.1 ± 0.8                  |                                   |

a : Values are mean ± SEM. b : Significantly different from the 0 wk value by t-test (paired. \* ; p < 0.05. \*\* ; p < 0.01). c : Significantly different from control group by t-test (unpaired. \* ; p < 0.05).

#### **5. Change in Blood Chemistry and Hematology Test Variables**

TG differed significantly between the groups in week 8 (test period) and was significantly higher in the catechins group than in the control group throughout the test period (Table 4). NEFA differed significantly between the groups in week 24 (washout period) (Table 4). There was a difference in Alb and Ca between the groups in week 12 (test period) (Table 4). FBS differed between the groups in week 0 (Table 4). Mean NEFA, Alb, FBS and Ca were within the normal range. For the other variables, there were significant differences when compared with week 0 but no differences between the groups (Table 4).

#### **6. Change in Urinalysis Results and Effect on Physical Condition**

The urinalysis results showed no major changes in any of the subjects. Nor did any of the subjects complain of being in poor physical condition due to ingestion of the test beverage in interviews.

#### **7. Analysis of Measured Values for Physical Parameters and Abdominal Fat Area by Sex**

There were no significant differences in the values for any of the variables in week 0 between the groups for each sex (Tables 5 and 6).

Change in the TFA, VFA and SFA in the men in week 12 (test period) was significantly lower in the catechins group than in the control group (Table 5). Change in the hip circumference in the men was also significantly lower in the catechins group than in the control group throughout the test period (Table 5). In the women, change in body weight, BMI, body fat percentage and body fat mass was significantly lower in the catechins group than in the control group throughout the test period (Table 6).

## **8. Analysis of Abdominal Fat Area by Obesity Status**

The subjects were selected on the basis of BMI in this study, but because body fat mass is not reflected by BMI alone, an analysis of the abdominal fat area subgroups was also conducted using body fat as the criterion.

Abdominal fat was investigated in the subjects with slight obesity (men: body fat percentage  $\geq 20\%$ ; women: body fat percentage  $\geq 30\%$ )<sup>25</sup> based on the body fat percentage in week 0. For the TFA, the measured values in the men and women combined, the men and the women in the catechins group in week 12 (test period) and week 24 (washout period) were significantly lower, and change in the men and women combined and the men in week 12 (test period) and week 24 (washout period) and change in the women in week 12 (test period) were significantly lower in the catechins group than in the control group (Table 7). For the VFA, the measured values in the men and women combined and the men in the catechins group in week 12 (test period) and week 24 (washout period) were significantly lower, and change in the men and women combined in week 12 (test period) and in the men in week 12 (test period) and week 24 (washout period) was significantly lower in the catechins group than in the control group (Table 7). For the SFA, the measured values in the men and women combined and the women in week 12 (test period) and week 24 (washout period) and the measured values in the men in week 12 (test period) in the catechins groups were significantly lower, and change in the men and women combined in week 12 (test period) and week 24 (washout period) and in the women in week 12 (test period) were significantly lower in the catechins group than in the control group (Table 7).

Investigation of the abdominal fat area in the subjects with a VFA of greater than  $100 \text{ cm}^2$  and less than  $150 \text{ cm}^2$  in week 0 showed that for the TFA, the measured values in the men and women combined in week 12 (test period) and week 24 (washout period) and the measured values in the men and the women in week 12 (test period) in the catechins group (Table 8) were significantly lower. The measured values in the women in the control group in week 24 (washout period) were also significantly lower (Table 8). Change in the men and women combined and the men in week 12 (test period) was significantly lower in the catechins group than in the control group (Table 8). For the VFA, the measured values in the men in

the control group in week 12 (test period) were significantly higher, the measured values in the men in the catechins group in week 12 (test period) were significantly lower, and there was a significant difference between the measured values in the two groups in week 12 (test period) and week 24 (washout period) (Table 8). Change in the VFA in the men in week 12 (test period) was also significantly lower in the catechins group than in the control group (Table 8). For the SFA, the measured values in the men and women combined in week 12 (test period) and the women in week 12 (test period) and week 24 (washout period) in the catechins group were significantly lower, but there were no significant differences between either group (Table 8).



Table 5 Effects of catechin administration on

|                  |                   |                     | Test period    |                              |                              |
|------------------|-------------------|---------------------|----------------|------------------------------|------------------------------|
|                  |                   |                     | 0 wk           | 4 wks                        | 8 wks                        |
| Weight           | Control (n = 23)  | kg                  | 77.14 ± 2.34   | 77.10 ± 2.47                 | 76.53 ± 2.53                 |
|                  |                   | Δ kg                |                | -0.03 ± 0.32 <sup>b</sup>    | -0.60 ± 0.51                 |
|                  | Catechin (n = 20) | kg                  | 78.16 ± 2.21   | 77.48 ± 2.30 <sup>a, h</sup> | 76.95 ± 2.38 <sup>a, h</sup> |
|                  |                   | Δ kg                |                | -0.68 ± 0.26                 | -1.22 ± 0.39                 |
| BMI              | Control (n = 23)  | kg/m <sup>2</sup>   | 26.35 ± 0.46   | 26.33 ± 0.50                 | 26.14 ± 0.53                 |
|                  |                   | Δ kg/m <sup>2</sup> |                | -0.02 ± 0.10                 | -0.21 ± 0.16                 |
|                  | Catechin (n = 20) | kg/m <sup>2</sup>   | 26.73 ± 0.54   | 26.48 ± 0.53 <sup>a</sup>    | 26.29 ± 0.54 <sup>a, h</sup> |
|                  |                   | Δ kg/m <sup>2</sup> |                | -0.25 ± 0.10                 | -0.45 ± 0.15                 |
| Body fat ratio   | Control (n = 23)  | %                   | 24.60 ± 0.88   | 24.49 ± 0.91                 | 23.86 ± 0.97                 |
|                  |                   | Δ %                 |                | -0.11 ± 0.40                 | -0.74 ± 0.62                 |
|                  | Catechin (n = 20) | %                   | 25.93 ± 1.22   | 25.53 ± 1.18                 | 25.31 ± 1.17                 |
|                  |                   | Δ %                 |                | -0.40 ± 0.23                 | -0.62 ± 0.42                 |
| Waist            | Control (n = 23)  | cm                  | 89.41 ± 2.04   | 88.90 ± 1.89                 | 88.03 ± 1.76                 |
|                  |                   | Δ cm                |                | -0.51 ± 0.32                 | -1.38 ± 0.68                 |
|                  | Catechin (n = 20) | cm                  | 89.86 ± 1.39   | 89.19 ± 1.46 <sup>a</sup>    | 88.35 ± 1.49 <sup>a, h</sup> |
|                  |                   | Δ cm                |                | -0.67 ± 0.30                 | -1.51 ± 0.50                 |
| Hip              | Control (n = 23)  | cm                  | 97.48 ± 1.30   | 97.43 ± 1.24                 | 97.33 ± 1.24                 |
|                  |                   | Δ cm                |                | -0.04 ± 0.35                 | -0.14 ± 0.40                 |
|                  | Catechin (n = 20) | cm                  | 99.33 ± 1.73   | 98.73 ± 1.75 <sup>a</sup>    | 98.32 ± 1.83 <sup>a, h</sup> |
|                  |                   | Δ cm                |                | -0.60 ± 0.23                 | -1.01 ± 0.34                 |
| W/H <sup>c</sup> | Control (n = 23)  |                     | 0.916 ± 0.013  | 0.911 ± 0.011                | 0.903 ± 0.010                |
|                  |                   | Δ                   |                | -0.005 ± 0.004               | -0.012 ± 0.006               |
|                  | Catechin (n = 20) |                     | 0.907 ± 0.012  | 0.905 ± 0.011                | 0.900 ± 0.011                |
|                  |                   | Δ                   |                | -0.002 ± 0.003               | -0.006 ± 0.004               |
| Body fat mass    | Control (n = 23)  | kg                  | 19.18 ± 1.17   | 19.15 ± 1.27                 | 18.57 ± 1.31                 |
|                  |                   | Δ kg                |                | -0.03 ± 0.39                 | -0.61 ± 0.57                 |
|                  | Catechin (n = 20) | kg                  | 20.55 ± 1.46   | 20.08 ± 1.46 <sup>a</sup>    | 19.79 ± 1.48                 |
|                  |                   | Δ kg                |                | -0.46 ± 0.22                 | -0.76 ± 0.37                 |
| Lean body mass   | Control (n = 23)  | kg                  | 57.96 ± 1.50   | 57.95 ± 1.49                 | 57.96 ± 1.51                 |
|                  |                   | Δ kg                |                | 0.00 ± 0.27                  | 0.00 ± 0.46                  |
|                  | Catechin (n = 20) | kg                  | 57.61 ± 1.32   | 57.40 ± 1.36                 | 57.15 ± 1.40                 |
|                  |                   | Δ kg                |                | -0.20 ± 0.18                 | -0.45 ± 0.32                 |
| TFA <sup>d</sup> | Control (n = 23)  | cm <sup>2</sup>     | 297.15 ± 23.71 |                              |                              |
|                  |                   | Δ cm <sup>2</sup>   |                |                              |                              |
|                  | Catechin (n = 20) | cm <sup>2</sup>     | 314.75 ± 20.42 |                              |                              |
|                  |                   | Δ cm <sup>2</sup>   |                |                              |                              |
| VFA <sup>e</sup> | Control (n = 23)  | cm <sup>2</sup>     | 117.59 ± 9.78  |                              |                              |
|                  |                   | Δ cm <sup>2</sup>   |                |                              |                              |
|                  | Catechin (n = 20) | cm <sup>2</sup>     | 122.70 ± 9.95  |                              |                              |
|                  |                   | Δ cm <sup>2</sup>   |                |                              |                              |
| SFA <sup>f</sup> | Control (n = 23)  | cm <sup>2</sup>     | 179.55 ± 15.91 |                              |                              |
|                  |                   | Δ cm <sup>2</sup>   |                |                              |                              |
|                  | Catechin (n = 20) | cm <sup>2</sup>     | 192.04 ± 14.46 |                              |                              |
|                  |                   | Δ cm <sup>2</sup>   |                |                              |                              |

a : Values are mean ± SEM., b : Change from 0wk., c : Waist to hip circumference ratio., d : Total the 0wk value by t-test (paired. \* ; p < 0.05. \*\* ; p < 0.01)., h : Significantly different from control group

**body indices classified by gender(male) \***

| Wash out period  |                 |                |                  | P value of ANOVA<br>(Test period) |
|------------------|-----------------|----------------|------------------|-----------------------------------|
| 12 wks           | 16 wks          | 20 wks         | 24 wks           |                                   |
| 76.50 ± 2.58     | 76.48 ± 2.61    | 76.30 ± 2.55   | 76.61 ± 2.65     |                                   |
| -0.64 ± 0.61     | -0.66 ± 0.58    | -0.84 ± 0.50   | -0.53 ± 0.63     |                                   |
| 76.39 ± 2.27**   | 77.27 ± 2.25    | 77.63 ± 2.28   | 77.75 ± 2.28     | 0.9016                            |
| -1.78 ± 0.40     | -0.90 ± 0.43    | -0.54 ± 0.44   | -0.41 ± 0.46     | 0.1794                            |
| 26.12 ± 0.55     | 26.11 ± 0.54    | 26.05 ± 0.53   | 26.15 ± 0.56     |                                   |
| -0.23 ± 0.19     | -0.25 ± 0.18    | -0.30 ± 0.16   | -0.21 ± 0.20     |                                   |
| 26.10 ± 0.51**   | 26.41 ± 0.51    | 26.53 ± 0.51   | 26.57 ± 0.51     | 0.8309                            |
| -0.63 ± 0.15     | -0.33 ± 0.17    | -0.21 ± 0.17   | -0.16 ± 0.18     | 0.1528                            |
| 24.02 ± 0.98     | 23.31 ± 0.85*   | 23.17 ± 0.77*  | 23.38 ± 0.77*    |                                   |
| -0.58 ± 0.63     | -1.29 ± 0.54    | -1.43 ± 0.53   | -1.22 ± 0.55     |                                   |
| 24.32 ± 1.21**   | 25.43 ± 1.14    | 25.86 ± 1.11*  | 26.16 ± 1.12*    | 0.4809                            |
| -1.61 ± 0.51     | -0.50 ± 0.49    | -0.07 ± 0.44   | 0.23 ± 0.41*     | 0.5318                            |
| 88.45 ± 1.90     | 87.93 ± 1.87    | 88.10 ± 1.87   | 88.11 ± 1.86     |                                   |
| -0.97 ± 0.83     | -1.49 ± 0.96    | -1.31 ± 0.83   | -1.30 ± 0.87     |                                   |
| 87.91 ± 1.42**   | 88.60 ± 1.44**  | 89.16 ± 1.46   | 89.30 ± 1.46     | 0.9585                            |
| -1.95 ± 0.38     | -1.26 ± 0.44    | -0.70 ± 0.43   | -0.56 ± 0.43     | 0.5618                            |
| 97.66 ± 1.28     | 97.69 ± 1.30    | 97.64 ± 1.30   | 97.57 ± 1.32     |                                   |
| 0.18 ± 0.62      | 0.21 ± 0.64     | 0.17 ± 0.65    | 0.09 ± 0.67      |                                   |
| 97.68 ± 1.77**   | 98.08 ± 1.75**  | 98.43 ± 1.78** | 98.70 ± 1.75*    | 0.6258                            |
| -1.65 ± 0.34**   | -1.25 ± 0.31    | -0.90 ± 0.30   | -0.63 ± 0.26     | 0.0282                            |
| 0.904 ± 0.011*   | 0.899 ± 0.011*  | 0.901 ± 0.011* | 0.902 ± 0.010*   |                                   |
| -0.012 ± 0.005   | -0.017 ± 0.006  | -0.015 ± 0.006 | -0.014 ± 0.006   |                                   |
| 0.902 ± 0.011    | 0.905 ± 0.010   | 0.907 ± 0.010  | 0.906 ± 0.011    | 0.6969                            |
| -0.005 ± 0.003   | -0.002 ± 0.004* | 0.001 ± 0.003* | 0.000 ± 0.003*   | 0.4292                            |
| 18.71 ± 1.36     | 18.02 ± 1.08*   | 17.84 ± 1.00** | 18.09 ± 1.05*    |                                   |
| -0.47 ± 0.61     | -1.16 ± 0.43    | -1.34 ± 0.45   | -1.09 ± 0.45     |                                   |
| 18.86 ± 1.43**   | 19.93 ± 1.42    | 20.35 ± 1.41   | 20.62 ± 1.42     | 0.6313                            |
| -1.70 ± 0.50     | -0.63 ± 0.49    | -0.20 ± 0.45   | 0.07 ± 0.42      | 0.3168                            |
| 57.79 ± 1.51     | 58.46 ± 1.80    | 58.46 ± 1.77   | 58.52 ± 1.82     |                                   |
| -0.17 ± 0.39     | 0.51 ± 0.69     | 0.50 ± 0.63    | 0.56 ± 0.69      |                                   |
| 57.53 ± 1.44     | 57.34 ± 1.36    | 57.27 ± 1.35   | 57.13 ± 1.34**   | 0.8108                            |
| -0.08 ± 0.34     | -0.27 ± 0.29    | -0.33 ± 0.19   | -0.48 ± 0.16     | 0.6641                            |
| 294.79 ± 23.46   |                 |                | 296.05 ± 25.49   |                                   |
| -2.35 ± 5.05     |                 |                | -1.09 ± 7.75     |                                   |
| 287.02 ± 20.62** |                 |                | 287.22 ± 18.86** |                                   |
| -27.72 ± 4.33**  |                 |                | -27.53 ± 9.56*   |                                   |
| 118.46 ± 9.48    |                 |                | 116.02 ± 9.16    |                                   |
| 0.87 ± 3.40      |                 |                | -1.57 ± 3.84     |                                   |
| 108.21 ± 8.91**  |                 |                | 107.40 ± 7.59**  |                                   |
| -14.49 ± 3.18**  |                 |                | -15.30 ± 4.63*   |                                   |
| 176.33 ± 15.89   |                 |                | 180.04 ± 17.91   |                                   |
| -3.21 ± 2.09     |                 |                | 0.49 ± 4.70      |                                   |
| 178.81 ± 15.45** |                 |                | 179.81 ± 16.03   |                                   |
| -13.23 ± 3.96*   |                 |                | -12.23 ± 7.52    |                                   |

fat area, e : Visceral fat area, f : Subcutaneous fat area, g : Significantly different from by t-test (unpaired, \* ; p < 0.05, \*\* ; p < 0.01).

Table 6 Effects of catechin administration on

|                  |                   |                     | Test period    |                            |                |
|------------------|-------------------|---------------------|----------------|----------------------------|----------------|
|                  |                   |                     | 0 wk           | 4 wks                      | 8 wks          |
| Weight           | Control (n = 18)  | kg                  | 61.70 ± 2.12   | 61.83 ± 2.31               | 61.67 ± 2.20   |
|                  |                   | Δ kg                |                | 0.13 ± 0.26                | -0.03 ± 0.25   |
|                  | Catechin (n = 19) | kg                  | 62.82 ± 1.62   | 62.42 ± 1.66               | 61.92 ± 1.70** |
|                  |                   | Δ kg                |                | -0.40 ± 0.30               | -0.89 ± 0.31*  |
| BMI              | Control (n = 18)  | kg/m <sup>2</sup>   | 25.68 ± 0.40   | 25.71 ± 0.46               | 25.66 ± 0.44   |
|                  |                   | Δ kg/m <sup>2</sup> |                | 0.03 ± 0.10                | -0.02 ± 0.11   |
|                  | Catechin (n = 19) | kg/m <sup>2</sup>   | 26.12 ± 0.51   | 25.96 ± 0.55               | 25.75 ± 0.56*  |
|                  |                   | Δ kg/m <sup>2</sup> |                | -0.16 ± 0.13               | -0.37 ± 0.13*  |
| Body fat ratio   | Control (n = 18)  | %                   | 32.56 ± 0.46   | 32.45 ± 0.48               | 32.79 ± 0.53   |
|                  |                   | Δ %                 |                | -0.11 ± 0.19               | 0.24 ± 0.27    |
|                  | Catechin (n = 19) | %                   | 32.19 ± 1.15   | 32.03 ± 1.22               | 31.52 ± 1.18*  |
|                  |                   | Δ %                 |                | -0.16 ± 0.27               | -0.68 ± 0.30*  |
| Waist            | Control (n = 19)  | cm                  | 82.06 ± 2.25   | 81.42 ± 2.32               | 80.89 ± 2.30   |
|                  |                   | Δ cm                |                | -0.64 ± 0.39               | -1.17 ± 0.63   |
|                  | Catechin (n = 19) | cm                  | 80.29 ± 2.12   | 80.03 ± 2.05               | 79.61 ± 2.02*  |
|                  |                   | Δ cm                |                | -0.26 ± 0.23               | -0.68 ± 0.32   |
| Hip              | Control (n = 18)  | cm                  | 97.81 ± 2.07   | 97.94 ± 2.20               | 97.58 ± 2.22   |
|                  |                   | Δ cm                |                | 0.14 ± 0.44                | -0.22 ± 0.55   |
|                  | Catechin (n = 19) | cm                  | 97.41 ± 0.99   | 96.96 ± 0.98**             | 96.58 ± 1.00*  |
|                  |                   | Δ cm                |                | -0.45 ± 0.20               | -0.83 ± 0.32   |
| W/H <sup>c</sup> | Control (n = 18)  |                     | 0.839 ± 0.014  | 0.831 ± 0.015              | 0.829 ± 0.015  |
|                  |                   | Δ                   |                | -0.008 ± 0.004             | -0.010 ± 0.006 |
|                  | Catechin (n = 19) |                     | 0.823 ± 0.017  | 0.825 ± 0.017              | 0.824 ± 0.017  |
|                  |                   | Δ                   |                | 0.001 ± 0.002 <sup>h</sup> | 0.000 ± 0.002  |
| Body fat mass    | Control (n = 18)  | kg                  | 20.12 ± 0.80   | 20.09 ± 0.86               | 20.24 ± 0.82   |
|                  |                   | Δ kg                |                | -0.03 ± 0.16               | 0.12 ± 0.21    |
|                  | Catechin (n = 19) | kg                  | 20.42 ± 1.17   | 20.21 ± 1.22               | 19.71 ± 1.18** |
|                  |                   | Δ kg                |                | -0.21 ± 0.21               | -0.71 ± 0.24*  |
| Lean body mass   | Control (n = 18)  | kg                  | 41.58 ± 1.39   | 41.74 ± 1.52               | 41.43 ± 1.48   |
|                  |                   | Δ kg                |                | 0.15 ± 0.16                | -0.15 ± 0.17   |
|                  | Catechin (n = 19) | kg                  | 42.39 ± 0.90   | 42.21 ± 0.93               | 42.21 ± 0.99   |
|                  |                   | Δ kg                |                | -0.19 ± 0.28               | -0.19 ± 0.27   |
| TFA <sup>d</sup> | Control (n = 18)  | cm <sup>2</sup>     | 335.20 ± 19.75 |                            |                |
|                  |                   | Δ cm <sup>2</sup>   |                |                            |                |
|                  | Catechin (n = 19) | cm <sup>2</sup>     | 340.38 ± 24.83 |                            |                |
|                  |                   | Δ cm <sup>2</sup>   |                |                            |                |
| VFA <sup>e</sup> | Control (n = 18)  | cm <sup>2</sup>     | 100.05 ± 10.53 |                            |                |
|                  |                   | Δ cm <sup>2</sup>   |                |                            |                |
|                  | Catechin (n = 19) | cm <sup>2</sup>     | 104.95 ± 11.25 |                            |                |
|                  |                   | Δ cm <sup>2</sup>   |                |                            |                |
| SFA <sup>f</sup> | Control (n = 18)  | cm <sup>2</sup>     | 235.16 ± 12.74 |                            |                |
|                  |                   | Δ cm <sup>2</sup>   |                |                            |                |
|                  | Catechin (n = 19) | cm <sup>2</sup>     | 235.43 ± 16.35 |                            |                |
|                  |                   | Δ cm <sup>2</sup>   |                |                            |                |

a : Values are mean ± SEM. b : Change from 0wk. c : Waist to hip circumference ratio. d : Total the 0wk value by t-test (paired. \* ; p < 0.05. \*\* ; p < 0.01). h : Significantly different from control group

body indices classified by gender (female)

| 12 wks           | Wash out period |                |                 | P value of ANOVA<br>(Test period) |
|------------------|-----------------|----------------|-----------------|-----------------------------------|
|                  | 16 wks          | 20 wks         | 24 wks          |                                   |
| 61.51 ± 2.29     | 61.24 ± 2.33    | 61.40 ± 2.31   | 61.43 ± 2.31    |                                   |
| -0.19 ± 0.36     | -0.46 ± 0.36    | -0.30 ± 0.32   | -0.27 ± 0.32    |                                   |
| 61.22 ± 1.72**   | 61.91 ± 1.67**  | 62.28 ± 1.66   | 62.77 ± 1.71    | 0.8811                            |
| -1.60 ± 0.39*    | -0.91 ± 0.29    | -0.53 ± 0.27   | -0.04 ± 0.28    | 0.0285                            |
| 25.58 ± 0.46     | 25.46 ± 0.47    | 25.53 ± 0.47   | 25.54 ± 0.47    |                                   |
| -0.10 ± 0.14     | -0.21 ± 0.14    | -0.14 ± 0.12   | -0.13 ± 0.13    |                                   |
| 25.44 ± 0.55**   | 25.74 ± 0.54**  | 25.90 ± 0.54   | 26.11 ± 0.57    | 0.8155                            |
| -0.68 ± 0.17*    | -0.38 ± 0.12    | -0.22 ± 0.11   | -0.01 ± 0.12    | 0.0280                            |
| 33.00 ± 0.51     | 34.03 ± 0.84    | 33.78 ± 0.80   | 33.58 ± 0.79    |                                   |
| 0.44 ± 0.39      | 1.48 ± 0.84     | 1.22 ± 0.79    | 1.02 ± 0.78     |                                   |
| 30.78 ± 1.22**   | 32.27 ± 1.18    | 33.19 ± 1.14   | 33.14 ± 1.16    | 0.4146                            |
| -1.42 ± 0.38**   | 0.07 ± 0.66     | 0.99 ± 0.63    | 0.94 ± 0.46     | 0.0195                            |
| 80.25 ± 2.52     | 80.54 ± 2.45    | 80.69 ± 2.40   | 80.73 ± 2.43    |                                   |
| -1.81 ± 0.94     | -1.52 ± 0.91    | -1.36 ± 0.85   | -1.32 ± 0.86    |                                   |
| 78.50 ± 2.05**   | 79.60 ± 2.06    | 79.84 ± 2.10   | 80.22 ± 2.12    | 0.6188                            |
| -1.79 ± 0.47     | -0.69 ± 0.46    | -0.45 ± 0.41   | -0.07 ± 0.38    | 0.6555                            |
| 97.33 ± 2.29     | 97.50 ± 2.24    | 97.86 ± 2.49   | 97.51 ± 2.24    |                                   |
| -0.47 ± 0.52     | -0.31 ± 0.57    | 0.06 ± 0.70    | -0.30 ± 0.50    |                                   |
| 96.00 ± 1.14**   | 96.06 ± 0.91    | 97.16 ± 1.10   | 97.35 ± 1.15    | 0.6957                            |
| -1.41 ± 0.45     | -1.34 ± 0.56    | -0.25 ± 0.36   | -0.05 ± 0.42    | 0.2049                            |
| 0.824 ± 0.015    | 0.826 ± 0.016   | 0.825 ± 0.015  | 0.828 ± 0.016   |                                   |
| -0.015 ± 0.010   | -0.013 ± 0.010  | -0.014 ± 0.010 | -0.011 ± 0.010  |                                   |
| 0.817 ± 0.017    | 0.828 ± 0.018   | 0.821 ± 0.017  | 0.823 ± 0.017   | 0.6742                            |
| -0.006 ± 0.004   | 0.005 ± 0.006   | -0.002 ± 0.003 | 0.000 ± 0.003   | 0.1599                            |
| 20.32 ± 0.86     | 21.04 ± 1.35    | 20.95 ± 1.35   | 20.85 ± 1.36    |                                   |
| 0.20 ± 0.28      | 0.93 ± 0.74     | 0.83 ± 0.73    | 0.73 ± 0.73     |                                   |
| 19.05 ± 1.21**   | 20.16 ± 1.16    | 20.88 ± 1.17   | 21.03 ± 1.24    | 0.8164                            |
| -1.37 ± 0.31**   | -0.27 ± 0.41    | 0.45 ± 0.41    | 0.61 ± 0.33     | 0.0082                            |
| 41.19 ± 1.52     | 40.20 ± 1.14*   | 40.45 ± 1.10   | 40.58 ± 1.09    |                                   |
| -0.40 ± 0.27     | -1.38 ± 0.59    | -1.13 ± 0.57   | -1.00 ± 0.58    |                                   |
| 42.16 ± 1.01     | 41.75 ± 1.01    | 41.41 ± 0.90*  | 41.74 ± 0.88*   | 0.6648                            |
| -0.23 ± 0.31     | -0.65 ± 0.50    | -0.99 ± 0.44   | -0.65 ± 0.31    | 0.8242                            |
| 333.97 ± 22.80   |                 |                | 329.69 ± 22.91  |                                   |
| -1.23 ± 9.88     |                 |                | -5.51 ± 11.31   |                                   |
| 315.43 ± 24.88** |                 |                | 317.86 ± 23.56* |                                   |
| -24.95 ± 6.47    |                 |                | -22.52 ± 9.26   |                                   |
| 99.60 ± 10.85    |                 |                | 97.44 ± 11.77   |                                   |
| -0.45 ± 3.78     |                 |                | -2.61 ± 4.48    |                                   |
| 102.32 ± 12.23   |                 |                | 99.28 ± 11.59   |                                   |
| -2.62 ± 3.39     |                 |                | -5.67 ± 5.49    |                                   |
| 234.36 ± 14.40   |                 |                | 232.24 ± 15.31  |                                   |
| -0.80 ± 8.26     |                 |                | -2.92 ± 9.66    |                                   |
| 213.10 ± 14.94** |                 |                | 218.58 ± 14.14* |                                   |
| -22.33 ± 7.12    |                 |                | -16.85 ± 7.80   |                                   |

fat area, e : Visceral fat area, f : Subcutaneous fat area, g : Significantly different from by t-test (unpaired. \* : p < 0.05, \*\* : p < 0.01).

**Table 7** Effects of catechin administration on fat area classified by body fat ratio (male ; 20% and more, female ; 30% and more at 0wk) <sup>a</sup>

|                  |                   |                                | Test period                    |                              | Wash out period              |
|------------------|-------------------|--------------------------------|--------------------------------|------------------------------|------------------------------|
|                  |                   |                                | 0 wk                           | 12 wks                       | 24 wks                       |
| TFA <sup>c</sup> | Total             | Control (n = 35)               | cm <sup>2</sup> 321.01 ± 17.29 | 322.75 ± 17.86               | 321.34 ± 19.20               |
|                  |                   |                                | Δ cm <sup>2</sup>              | 1.75 ± 4.96 <sup>b</sup>     | 0.34 ± 6.93                  |
|                  |                   | Catechin (n = 29)              | cm <sup>2</sup> 342.24 ± 18.56 | 312.94 ± 18.83 <sup>*f</sup> | 311.89 ± 17.64 <sup>**</sup> |
|                  |                   |                                | Δ cm <sup>2</sup>              | -29.30 ± 4.63 <sup>**g</sup> | -30.35 ± 7.97 <sup>**</sup>  |
|                  | Male              | Control (n = 19)               | cm <sup>2</sup> 310.48 ± 26.09 | 307.63 ± 25.30               | 311.78 ± 28.60               |
|                  |                   |                                | Δ cm <sup>2</sup>              | -2.85 ± 5.83                 | 1.30 ± 9.07                  |
|                  | Catechin (n = 18) | cm <sup>2</sup> 325.92 ± 21.07 | 298.39 ± 21.24 <sup>**</sup>   | 295.77 ± 19.92 <sup>*</sup>  |                              |
|                  |                   | Δ cm <sup>2</sup>              | -27.53 ± 4.78 <sup>**</sup>    | -30.15 ± 10.44 <sup>*</sup>  |                              |
| Female           | Control (n = 16)  | cm <sup>2</sup> 333.51 ± 22.23 | 340.72 ± 25.11                 | 332.70 ± 25.42               |                              |
|                  |                   | Δ cm <sup>2</sup>              | 7.21 ± 8.37                    | -0.80 ± 10.99                |                              |
|                  | Catechin (n = 11) | cm <sup>2</sup> 368.94 ± 34.55 | 336.76 ± 35.65 <sup>**</sup>   | 338.27 ± 32.87 <sup>*</sup>  |                              |
|                  |                   | Δ cm <sup>2</sup>              | -32.18 ± 9.67 <sup>**</sup>    | -30.67 ± 12.88               |                              |
| VFA <sup>d</sup> | Total             | Control (n = 35)               | cm <sup>2</sup> 112.02 ± 8.10  | 112.38 ± 7.80                | 110.47 ± 8.21                |
|                  |                   |                                | Δ cm <sup>2</sup>              | 0.37 ± 2.65                  | -1.54 ± 3.25                 |
|                  |                   | Catechin (n = 29)              | cm <sup>2</sup> 120.10 ± 9.26  | 110.00 ± 9.13 <sup>**</sup>  | 107.50 ± 8.34 <sup>*</sup>   |
|                  |                   |                                | Δ cm <sup>2</sup>              | -10.10 ± 3.15 <sup>*</sup>   | -12.59 ± 4.71                |
|                  | Male              | Control (n = 19)               | cm <sup>2</sup> 121.86 ± 10.85 | 122.11 ± 10.08               | 120.73 ± 10.11               |
|                  |                   |                                | Δ cm <sup>2</sup>              | 0.25 ± 3.90                  | -1.13 ± 4.57                 |
|                  | Catechin (n = 18) | cm <sup>2</sup> 125.05 ± 10.90 | 110.40 ± 9.73 <sup>**</sup>    | 108.23 ± 8.30 <sup>**</sup>  |                              |
|                  |                   | Δ cm <sup>2</sup>              | -14.66 ± 3.53 <sup>**</sup>    | -16.82 ± 5.00 <sup>*</sup>   |                              |
| Female           | Control (n = 16)  | cm <sup>2</sup> 100.32 ± 11.87 | 100.83 ± 11.85                 | 98.30 ± 13.05                |                              |
|                  |                   | Δ cm <sup>2</sup>              | 0.51 ± 3.61                    | -2.03 ± 4.76                 |                              |
|                  | Catechin (n = 11) | cm <sup>2</sup> 111.99 ± 17.10 | 109.35 ± 18.74                 | 106.32 ± 17.93               |                              |
|                  |                   | Δ cm <sup>2</sup>              | -2.64 ± 5.43                   | -5.68 ± 9.29                 |                              |
| SFA <sup>e</sup> | Total             | Control (n = 35)               | cm <sup>2</sup> 208.99 ± 12.09 | 210.37 ± 12.68               | 210.87 ± 13.87               |
|                  |                   |                                | Δ cm <sup>2</sup>              | 1.39 ± 3.58                  | 1.88 ± 5.26                  |
|                  |                   | Catechin (n = 29)              | cm <sup>2</sup> 222.14 ± 13.17 | 202.94 ± 12.69 <sup>**</sup> | 204.38 ± 12.73 <sup>*</sup>  |
|                  |                   |                                | Δ cm <sup>2</sup>              | -19.20 ± 5.16 <sup>**</sup>  | -17.76 ± 6.55 <sup>*</sup>   |
|                  | Male              | Control (n = 19)               | cm <sup>2</sup> 188.61 ± 17.81 | 185.53 ± 17.67               | 191.06 ± 20.40               |
|                  |                   |                                | Δ cm <sup>2</sup>              | -3.09 ± 2.44                 | 2.45 ± 5.45                  |
|                  | Catechin (n = 18) | cm <sup>2</sup> 200.86 ± 14.62 | 187.99 ± 15.71 <sup>**</sup>   | 187.54 ± 16.86               |                              |
|                  |                   | Δ cm <sup>2</sup>              | -12.87 ± 4.38                  | -13.33 ± 8.33                |                              |
| Female           | Control (n = 16)  | cm <sup>2</sup> 233.18 ± 14.17 | 239.88 ± 15.67                 | 234.40 ± 17.11               |                              |
|                  |                   | Δ cm <sup>2</sup>              | 6.69 ± 7.19                    | 1.21 ± 9.73                  |                              |
|                  | Catechin (n = 11) | cm <sup>2</sup> 256.96 ± 22.17 | 227.41 ± 20.11 <sup>*</sup>    | 231.95 ± 16.81 <sup>*</sup>  |                              |
|                  |                   | Δ cm <sup>2</sup>              | -29.55 ± 11.22 <sup>**</sup>   | -25.01 ± 10.71               |                              |

<sup>a</sup> : Values are mean ± SEM. <sup>b</sup> : Change from 0wk value as 0. <sup>c</sup> : Total fat area. <sup>d</sup> : Visceral fat area. <sup>e</sup> : Subcutaneous fat area. <sup>f</sup> : Significantly different from the 0wk value by t-test (paired. \* : p < 0.05, \*\* : p < 0.01). <sup>g</sup> : Significantly different from control group by t-test (unpaired. \* ; p < 0.05, \*\* ; p < 0.01).

**Table 8** Effects of catechin administration on fat area classified by VFA (100-150 cm<sup>2</sup> at 0wk)<sup>a</sup>

|                  |                  |                   | Test period       |                              | Wash out period                |                             |
|------------------|------------------|-------------------|-------------------|------------------------------|--------------------------------|-----------------------------|
|                  |                  |                   | 0 wk              | 12 wk                        | 24 wk                          |                             |
| TFA <sup>c</sup> | Total            | Control (n = 15)  | cm <sup>2</sup>   | 340.02 ± 12.76               | 341.32 ± 15.88                 | 325.52 ± 14.64              |
|                  |                  |                   | Δ cm <sup>2</sup> |                              | 1.30 ± 6.28 <sup>b</sup>       | -14.51 ± 7.69               |
|                  |                  | Catechin (n = 13) | cm <sup>2</sup>   | 361.19 ± 23.44               | 343.60 ± 24.53 <sup>***f</sup> | 342.10 ± 24.66 <sup>*</sup> |
|                  |                  |                   | Δ cm <sup>2</sup> |                              | -17.59 ± 4.46 <sup>***e</sup>  | -19.09 ± 8.17               |
|                  | Male             | Control (n = 7)   | cm <sup>2</sup>   | 316.92 ± 15.00               | 327.60 ± 20.77                 | 312.01 ± 24.15              |
|                  |                  |                   | Δ cm <sup>2</sup> |                              | 10.68 ± 9.17                   | -4.92 ± 12.47               |
| Female           | Catechin (n = 6) | cm <sup>2</sup>   | 316.35 ± 35.69    | 298.01 ± 38.76 <sup>*</sup>  | 306.21 ± 37.88                 |                             |
|                  |                  | Δ cm <sup>2</sup> |                   | -18.34 ± 7.10 <sup>*</sup>   | -10.13 ± 10.40                 |                             |
|                  | Control (n = 8)  | cm <sup>2</sup>   | 360.23 ± 17.80    | 353.33 ± 24.04               | 337.34 ± 17.99 <sup>*</sup>    |                             |
|                  |                  | Δ cm <sup>2</sup> |                   | -6.90 ± 8.02                 | -22.90 ± 9.14                  |                             |
|                  | Catechin (n = 7) | cm <sup>2</sup>   | 399.63 ± 24.46    | 382.68 ± 24.70 <sup>*</sup>  | 372.86 ± 29.86                 |                             |
|                  |                  | Δ cm <sup>2</sup> |                   | -16.95 ± 6.15                | -26.77 ± 12.22                 |                             |
| VFA <sup>d</sup> | Total            | Control (n = 15)  | cm <sup>2</sup>   | 125.01 ± 4.36                | 127.35 ± 5.90                  | 119.76 ± 6.83               |
|                  |                  |                   | Δ cm <sup>2</sup> |                              | 2.34 ± 4.30                    | -5.25 ± 5.39                |
|                  |                  | Catechin (n = 13) | cm <sup>2</sup>   | 122.20 ± 3.75                | 113.96 ± 5.75                  | 114.48 ± 6.28               |
|                  |                  |                   | Δ cm <sup>2</sup> |                              | -8.24 ± 4.17                   | -7.72 ± 6.90                |
|                  | Male             | Control (n = 7)   | cm <sup>2</sup>   | 127.31 ± 6.65                | 139.27 ± 6.61 <sup>*</sup>     | 125.78 ± 5.47               |
|                  |                  |                   | Δ cm <sup>2</sup> |                              | 11.96 ± 4.82                   | -1.53 ± 7.15                |
| Female           | Catechin (n = 6) | cm <sup>2</sup>   | 117.00 ± 3.36     | 100.70 ± 5.75 <sup>***</sup> | 104.55 ± 5.45 <sup>*</sup>     |                             |
|                  |                  | Δ cm <sup>2</sup> |                   | -16.30 ± 5.66 <sup>***</sup> | -12.45 ± 7.29                  |                             |
|                  | Control (n = 8)  | cm <sup>2</sup>   | 123.00 ± 6.08     | 116.92 ± 8.02                | 114.50 ± 12.00                 |                             |
|                  |                  | Δ cm <sup>2</sup> |                   | -6.08 ± 5.51                 | -8.51 ± 8.20                   |                             |
|                  | Catechin (n = 7) | cm <sup>2</sup>   | 126.66 ± 6.08     | 125.32 ± 7.26                | 123.00 ± 9.95                  |                             |
|                  |                  | Δ cm <sup>2</sup> |                   | -1.34 ± 4.94                 | -3.66 ± 11.54                  |                             |
| SFA <sup>e</sup> | Total            | Control (n = 15)  | cm <sup>2</sup>   | 215.01 ± 12.48               | 213.97 ± 14.42                 | 205.77 ± 12.26              |
|                  |                  |                   | Δ cm <sup>2</sup> |                              | -1.04 ± 5.46                   | -9.25 ± 7.16                |
|                  |                  | Catechin (n = 13) | cm <sup>2</sup>   | 238.99 ± 22.87               | 229.64 ± 21.80 <sup>**</sup>   | 227.61 ± 22.43              |
|                  |                  |                   | Δ cm <sup>2</sup> |                              | -9.34 ± 2.77                   | -11.38 ± 7.13               |
|                  | Male             | Control (n = 7)   | cm <sup>2</sup>   | 189.60 ± 18.00               | 188.34 ± 19.77                 | 186.25 ± 22.36              |
|                  |                  |                   | Δ cm <sup>2</sup> |                              | -1.27 ± 4.66                   | -3.36 ± 7.11                |
| Female           | Catechin (n = 6) | cm <sup>2</sup>   | 199.34 ± 35.50    | 197.31 ± 36.42               | 201.66 ± 39.54                 |                             |
|                  |                  | Δ cm <sup>2</sup> |                   | -2.03 ± 2.51                 | 2.32 ± 10.30                   |                             |
|                  | Control (n = 8)  | cm <sup>2</sup>   | 237.24 ± 13.78    | 236.41 ± 18.22               | 222.85 ± 9.95                  |                             |
|                  |                  | Δ cm <sup>2</sup> |                   | -0.83 ± 9.77                 | -14.40 ± 12.10                 |                             |
|                  | Catechin (n = 7) | cm <sup>2</sup>   | 272.97 ± 25.03    | 257.35 ± 23.25 <sup>**</sup> | 249.85 ± 23.95 <sup>*</sup>    |                             |
|                  |                  | Δ cm <sup>2</sup> |                   | -15.61 ± 3.13                | -23.11 ± 7.95                  |                             |

a : Values are mean ± SEM. b : Change from 0wk value as 0. c : Total fat area. d : Visceral fat area. e : Subcutaneous fat area. f : Significantly different from the 0wk value by t-test (paired. \* ; p < 0.05, \*\* ; p < 0.01). , g : Significantly different from control group by t-test (unpaired. \* ; p < 0.05, \*\* ; p < 0.01).

## DISCUSSION

The study was conducted to investigate decrease in body fat and change in blood constituents as a result of ingestion of catechins in men and postmenopausal women. The results showed that the measured value for the VFA in the men differed significantly between the groups in subjects with a VFA of greater than 100 cm<sup>2</sup> and less than 150 cm<sup>2</sup> in week 0. In the other analysis results, comparison of change in the body-fat-related variables between the groups showed that ingestion of catechins reduced body fat. TG, NEFA and Alb also differed between the groups, but this appeared to have been due mainly to differences in the values in week 0 rather than to ingestion of catechins because there were no changes in any of these variables relative to week 0 at the measurement points when significant differences were seen. It was also concluded that ingestion of catechins at a dose of 588 mg/day, at which level body fat was reduced, is safe because there were no major changes in the other blood chemistry and hematology variables or in the urinalysis and interview results.

It has been known for some time that visceral fat plays an important role in lifestyle-related diseases and that men and postmenopausal women who tend to accumulate visceral fat are at high risk of developing these diseases.<sup>26</sup> However, recent research has also shown that abdominal subcutaneous fat is involved in insulin resistance,<sup>3</sup> and it is believed that reducing abdominal fat helps to prevent and improve lifestyle-related diseases. The results of the current study show that catechins mainly reduce abdominal subcutaneous fat in women and visceral fat in men. Matsuzawa and coworkers also identified a relationship between VFA and the number of concurrent health problems.<sup>27</sup> It was predicted that the decrease in VFA seen in this study would reduce the number of concurrent health problems by approximately 0.1, suggesting that ingestion of catechins would help to avoid the risk of lifestyle-related diseases by decreasing abdominal fat.

The amount of body fat that accumulates is determined by the balance between energy intake and expenditure. Studies have suggested that catechins inhibit absorption of energy.<sup>25,29</sup> However, these studies have mainly been conducted in animals using high doses of catechins, and the relationship between these effects and

reduction in body fat due to ingestion of catechins in humans has not yet been rigorously investigated.

Meguro and coworkers observed a reduction in body fat following ingestion of catechins at a dose that does not inhibit sugar and fat absorption in an animal model of obesity,<sup>20</sup> suggesting that a mechanism other than inhibition of energy absorption may be responsible for the reduction in body fat by catechins. Recent studies have shown that catechins promote energy expenditure,<sup>17,19,30</sup> suggesting that they may have some effect on fat metabolism. Osaki and coworkers showed that catechins increase expenditure of fat-derived energy in rats<sup>31</sup> and Onizawa and coworkers found that catechins promote oxidation of dietary lipids in rats.<sup>32</sup> Murase and coworkers also showed that catechins induce  $\beta$ -oxidase group gene expression in the liver in mice.<sup>33</sup> These studies suggest that promotion of lipid metabolism by catechins played a role in the reduction in body fat seen in the current study.

### **CONCLUSIONS**

The results of this study confirmed that ingestion of catechins at a dose of 588 mg/day for 12 weeks reduces abdominal fat, particularly visceral fat in men and subcutaneous fat in women, a growing a problem in modern society, and helps to prevent and improve obesity and associated lifestyle-related diseases.

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I was initially confused by the way the Japanese article presented the results but just followed this. For example, when you say the change in body fat levels was significantly lower in a particular group, you assume there was less change, but because the change was negative (ie loss of fat), the Japanese article says a value is “lower” if the change is greater (for example, a change of -1 g is lower than a change of -0.5 g). I found that confusing but the reader will have to work that out I guess.

(Throughout article) The Japanese uses “sample ingestion period” which I have translated as “test beverage ingestion period” but the tables use “test period” so when this first appeared, I wrote it as “test beverage ingestion period (the test period)” and then just used “test period” throughout the rest of the article to match the tables.