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Catechin Safely Improved Higher Levels of Fatness, Blood Pressure, and Cholesterol in Children

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Objective: The purpose of this study was to evaluate the effects of a catechin-rich beverage on body fat and cardiovascular disease risk factors in obese children and to verify the safety of its use.

Methods and Procedures: Obese or near-obese Japanese children were recruited for this study. A double-blind, randomized, controlled study was performed with a 4-week lead-in, a 24-week beverage ingestion period and a 12-week follow-up. Subjects ingested green tea containing 576 mg catechins (catechin group) or 75 mg catechins (control group) once per day for 24 weeks. Randomization was stratified by gender, age, and BMI. Subjects were instructed to maintain their usual lifestyles during the study period.

Results: Data were analyzed using samples from 40 subjects (catechin group; $n = 21$, control group; $n = 19$). There were no significant differences in major outcome variables, such as body fat mass, between the catechin and the control groups. When, however, the analysis was stratified using the median of the week-0 values, the decrease at week 24 in waist circumference, systolic blood pressure, and low-density lipoprotein cholesterol in the catechin group was significantly greater than that in the control group for the above-median category. Ingestion of the catechin-rich beverage was not associated with any adverse effects.

Discussion: These findings suggest that ingestion of a catechin-rich beverage ameliorates serious obesity and cardiovascular disease risk factors without raising any safety concerns in Japanese children.

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INTRODUCTION

The increasing incidence of child obesity is a global issue. Between 1976 and 2000, BMI in Japanese boys and girls aged 6–14 years increased at a rate of +0.32 and 0.24 kg/m^2 per decade, respectively (1), and the prevalence of obesity (~10% in 1996–2000) continues to increase (1). Moreover, although the prevalence of child obesity in Japan is lower than that in the United States, the incidence of the metabolic syndrome, the criteria for which differ between these countries, is higher in Japanese children than in American children and may be due to hyperinsulinemia in girls and abdominal fat-type obesity in boys (2). Since 1976, the prevalence of type 2 diabetes mellitus in children has also increased, and this increase has been associated with increased ingestion of animal protein and fat and decreased exercise (3). Adults who have fewer risk factors for the metabolic syndrome during childhood have lower cardiovascular disease risk during adulthood (4). Thus, health status in childhood affects risk of developing the metabolic syndrome and cardiovascular disease during adulthood.

Green tea, a traditional Japanese beverage, contains low molecular weight polyphenols called catechins, consisting primarily of flavonol (flavan-3-ol) monomers: catechin, catechin gallate, gallocatechin, gallocatechin gallate, epicatechin, epicatechin gallate, epigallocatechin, and epigallocatechin gallate. Normally, green tea leaves contain 10–20% catechins, mainly epigallocatechin and epigallocatechin gallate (5). Catechins ingestion has physiologic effects, some of which are related to metabolic syndrome risk factors. Dulloo *et al.* concluded that the elevated oxygen consumption and decreased respiratory quotient (6) observed after catechins ingestion result from sympathetic nervous system-induced thermogenesis secondary to inhibition of catechol O-methyltransferase activity (7). Harada *et al.* proposed that enhanced dietary fat oxidation and increased dietary-induced thermogenesis (8) were due to increased β-oxidation in the liver (9). In addition, Chan *et al.* reported that the hypolipidemic effects of epicatechin were mediated by inhibition of dietary fat and cholesterol absorption (10). Abe *et al.* found that epigallocatechin gallate, gallocatechin gallate,

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and epicatechin gallate were potent and selective inhibitors of rat squalene epoxidase, the rate-limiting enzyme in cholesterol biosynthesis (11). The improvements of body fat, blood pressure, and cholesterol level by catechins ingestion, particularly at high doses (~600 mg/day ingestion), has been verified in human intervention studies (12). Most human studies, however, have been conducted in adult populations. In this study, the effect of daily ingestion of a catechin-rich beverage on body fat and cardiovascular disease risk factors and the safety of its use in obese Japanese children was investigated.

METHODS AND PROCEDURES

Test beverages

Green tea leaves (9 g) were extracted with 1 l of hot water (80 °C) for 5 min and the resulting aqueous extract comprised the base beverage. Catechin-rich green tea extract powder was added to the base beverage to adjust the concentration of catechins to ~600 mg/340 ml. Three-hundred and forty milliliter portions of the catechin-rich beverage were canned and sterilized by heating (final catechins content to decrease caused by heating: 576 mg/can). For the control beverage preparation, catechin-rich green tea extract powder was added to the base beverage (80 mg/340 ml) so that the two treatments could not be distinguished based on taste. In addition, the added catechin-rich green tea extract powder equalized the ratios of the catechins and the caffeine content between the control and the catechin-rich beverage. Following the same canning and sterilization procedure used for the catechin-rich beverage, the final catechins content of the control beverage was 75 mg/can. The catechin-rich and control beverages contained equivalent amounts of caffeine and the ratios of the eight catechins were similar (**Table 1**).

The canned beverage was packaged in boxes containing 24 cans per box. Each study subject received one box prior to the beverage ingestion period; additional boxes were supplied throughout the study before the 24 cans had been used up.

Subjects

Japanese female and male schoolchildren aged 6–16 year-old with a BMI of ≥28 kg/m^2 or who were judged to be obese by a physician were recruited for the trial. Subjects were recruited by website notification and by distribution of fliers in hospitals, and by announcements at neighboring schools in the Japanese cities of Fussa and Wako. There were five exclusion criteria: current treatment for obesity; severe systemic, liver, and renal disorders; hypersensitivity to caffeine or catechins; use of medications containing iron preparations; or judged to be ineligible by the study physician.

Table 1 Catechins and caffeine content of the test beverages

	Control beverage (% of total catechins)	Catechin-rich beverage (% of total catechins)
Total catechins (mg/100 ml)	22.2 (100.0)	169.4 (100.0)
Catechin	1.7 (7.8)	11.7 (6.9)
Catechin gallate	1.1 (5.1)	10.8 (6.4)
Gallocatechin	6.0 (27.0)	37.9 (22.4)
Gallocatechin gallate	5.1 (23.1)	39.9 (23.5)
Epicatechin	1.3 (6.0)	8.6 (5.1)
Epicatechin gallate	1.1 (5.2)	9.4 (5.6)
Epigallocatechin	2.3 (10.3)	21.0 (12.4)
Epigallocatechin gallate	3.4 (15.5)	30.1 (17.8)
Caffeine (mg/100 ml)	22.9	23.4
Total catechins/can (mg/340 ml)	75.4	575.9
Caffeine/can (mg/340 ml)	77.7	79.4

Study design and outcome measures

This study was approved by the Ethics Committees of Fussa Hospital (Fussa, Tokyo) and of the National Hospital Organization Saitama National Hospital (Wako, Saitama). During recruitment, the content, objective, and possible risks of the study were explained to potential subjects and their parents both in written form and orally by the study physician. Written informed consent was obtained from the subjects and their parents. The study was performed according to the Declaration of Helsinki under supervision of the principal investigator at two hospitals between January 2004 and August 2005.

A double-blind, randomized, controlled study, consisting of a 4-week lead-in period, a 24-week beverage ingestion period, and a 12-week follow-up period, was performed (**Figure 1**). Prior to the beverage ingestion period, the subjects were assigned to either the catechin (catechin-rich beverage ingestion) or the control (control beverage ingestion) group by stratified randomization at each hospital according to gender, age, and BMI, which was calculated from height and body weight measured at enrollment. The initiation of beverage ingestion was designated as week 0. During the 24-week beverage ingestion period, the subjects' parents were responsible for providing their children with the test beverage. Subjects consumed an entire 340 ml (1 can) of either the catechin-rich or the control beverage per day. Subjects consumed the entire 340 ml can at once and were permitted to drink the beverages at any time of the day.

The subjects were instructed to refrain from excess consumption of lipids, sugars, and beverages, such as carbonated beverages, cocoa, and coffee, and to maintain their usual exercise habits during the study period. Subjects were instructed to avoid ingesting foods that reduce excess adiposity (e.g., foods for specified health uses such as medium-chain fatty acids–fortified foods, globin digest–fortified foods, or catechins-fortified foods). Consumption of catechin-rich foods and beverages other than the test beverage was prohibited during the study period.

Ingestion of foods and beverages, except water, was prohibited after supper on the day prior to examination until all tests had been completed the following day. The test beverage was ingested after the testing was complete.

Anthropometry, blood pressure measurements, blood and urine collection were performed in the morning on the day of testing with subjects in the fasted condition.

The following anthropometric parameters were measured at weeks 0, 12, 24, and 36: height, body weight, waist circumference, hip circumference, lean body mass (LBM), body fat mass (BFM), and body fat ratio. In addition, visceral fat area (VFA) and subcutaneous fat area (SFA) were measured at weeks 0, 24, and 36. Waist circumference was measured at the level of the umbilicus and hip circumference was measured at the maximal gluteal circumference. LBM, BFM, and body fat ratio were measured using dual-energy X-ray absorptiometry of the whole body; VFA and SFA were measured by computed tomography at the L4/L5 intervertebral level. VFA and SFA were estimated from computed tomography images using the visceral fat measurement PC software, Fat Scan Ver. 2 (N2 System, Osaka, Japan), which was developed according to the method described by Tokunaga *et al.* (13). In addition, BMI (kg/m^2, = body weight (kg)/height (m^2)), obesity index (%, = (measured body weight (kg) – standard body weight (kg))/standard body weight (kg) × 100), and waist-to-hip ratio (waist circumference (cm)/hip circumference (cm)) were calculated. The standard body weight for normal Japanese individuals of the same height, age range, and gender was identified by the table prepared by Murata (14).

Systolic blood pressure (SBP) and diastolic blood pressures (DBP) were measured at weeks 0, 12, 24, and 36 using an automatic sphygmomanometer with subjects in the seated position after resting quietly for 10 min.

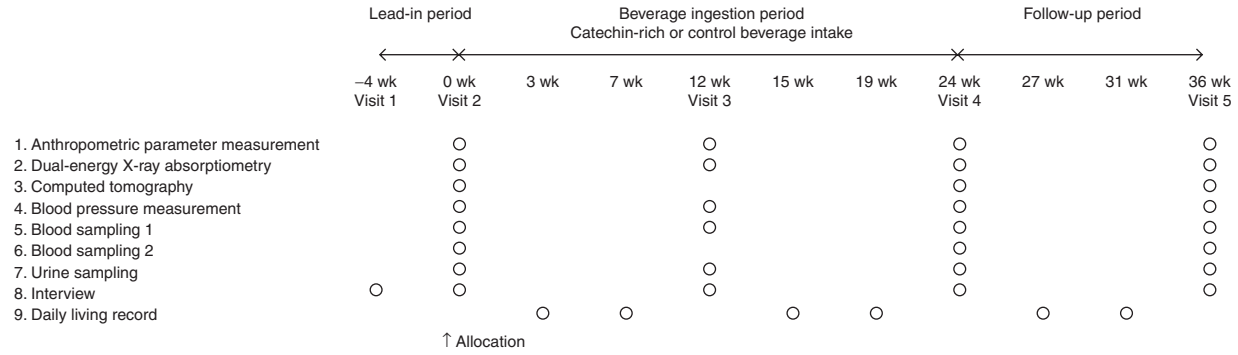

Figure 1 Schematic representation of the study protocol. 1: Anthropometric parameter measures included height, body weight, waist circumference, and hip circumference. 2: Dual-energy X-ray absorptiometry was carried out for the measurements of body fat mass, lean body mass, and body fat ratio. 3: Computed tomography was carried out for the measurements of visceral fat area and subcutaneous fat area. 4: Systolic blood pressure and diastolic blood pressure were measured. 5: Test items measured in blood sample 1 were as follows: triglyceride, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, free fatty acids, total ketone bodies, remnant-like lipoprotein particles cholesterol, glucose, alkaline phosphatase, lactate dehydrogenase, γ-glutamyl transpeptidase, aspartate aminotransferase, alanine aminotransferase, creatinine, uric acid, urea nitrogen, total protein, albumin, inorganic phosphate, calcium, iron, magnesium, sodium, potassium, chloride, white blood cell count, red blood cell count, hemoglobin, hematocrit, and platelet count. 6: Test items measured in blood sample 2 were leptin, growth hormone, high-sensitive C-reactive protein, and total plasminogen activator inhibitor-1. 7: Urinalysis included qualitative assessment of glucose, protein, urobilinogen, and ketone bodies. 8: In the subject interviews, a physician evaluated the physical condition and presence of symptoms of adverse effects of catechins ingestion. 9: The subjects or their parents recorded the intake of the test beverage, and daily activities for 3 days.

The following biochemical parameters were measured in serum at weeks 0, 12, 24, and 36: triglyceride, enzymatic method after eliminating endogenous free glycerol; total cholesterol (T-cho), cholesterol oxidase method; low-density lipoprotein cholesterol (LDL-cho), enzymatic method; high-density lipoprotein cholesterol (HDL-cho), selective inhibition method; free fatty acids, enzymatic method; total ketone bodies, enzymatic method; remnant-like lipoprotein particles cholesterol, immunosorbent assay; alkaline phosphatase, p-nitrophenyl phosphate substrate method; lactate dehydrogenase, Wroblewski-La-Due method; γ-glutamyl transpeptidase, L-glutamyl-3-carboxy-4-nitroanilide substrate method; aspartate aminotransferase, standardization-adjusted ultraviolet method; alanine aminotransferase, standardization-adjusted ultraviolet method; creatinine, enzymatic method; uric acid, uricase-peroxidase method; urea nitrogen, urease-ultraviolet method; total protein, biuret method; albumin, nephelometry; inorganic phosphate, molybdate method; calcium, o-cresol-phthalein complexone method; iron, 2-nitroso-5-[N-n-propyl-N-(3-sulfopropyl)amino]phenol method; magnesium, xylidyl blue method; sodium, electrode method; potassium, electrode method; and, chloride, electrode method. Glucose was measured in plasma using the glucose-dehydrogenase method at weeks 0, 12, 24, and 36. Leptin (Human Leptin RIA kit; LINCO Research, MO (15)) and growth hormone (GH kit "Daiichi"; TFB, Tokyo, Japan (16)) were measured using radioimmunoassay and high-sensitive C-reactive protein (HS CRP) was measured using latex-enhanced nephelometry (Behring BN II nephelometer and N latex CRP II; Siemens Healthcare Diagnostics, NY (17)) in serum at weeks 0, 24, and 36. Total plasminogen activator inhibitor-1 (PAI-1) was measured using a latex photometric immunoassay (LPIA·tPAI test; Mitsubishi Kagaku Iatron, Tokyo, Japan (18)) in plasma at weeks 0, 24, and 36. In addition, LDL-cho to HDL-cho ratio (LDL-cho/HDL-cho, = LDL-cho (mmol/l)/HDL-cho (mmol/l)) was calculated.

The following hematologic parameters were measured in whole blood using a hematocytometer at weeks 0, 12, 24, and 36: white blood cell count, red blood cell count, hemoglobin, hematocrit, and platelet count.

Spot urine samples were collected and qualitative testing of glucose, protein, urobilinogen, and ketone bodies was performed at weeks 0, 12, 24, and 36.

Analyses of biochemical and hematologic parameters and urinalysis were performed immediately after collecting blood and urine samples by a clinical laboratory testing service (SRL, Tachikawa, Tokyo, Japan).

Either the subjects or their parents recorded test beverage intake, physical condition, and daily activities, including eating habits and exercise, in a daily living record using a simple checklist for 3 of 7 days during weeks 3, 7, 15, 19, 27, and 31. Study investigators monitored the subjects' physical condition, occurrence of adverse effects, and compliance with the study protocol—consumption of the test beverage and maintenance of eating and exercise habits at each study visit by study personnel based on subject interviews and daily living records. Subjects were provided feedback based on the results of the interview and daily living record and were encouraged to maintain a constant level of daily activity.

Data analysis

Dropouts and missing data due to insufficient blood sample volumes or failure to comply with measurement protocol were replaced with the immediately preceding values. If a subject was missing week-12 data, then the week-0 data were used. Subjects who did not visit the hospital after week 0 were excluded from the data analysis. When week-0 data were missing, the subject was excluded from the analysis of that parameter. Changes from week 0 to week 24 also were calculated.

Statistically significant differences between groups at week 0 were determined using unpaired *t*-tests ($P < 0.05$). Two-way (group and time) repeated measures ANOVA was performed using the data collected during the beverage ingestion period (week 0–24; $P < 0.05$). If there were significant group or time effects, or a significant group-by-time interaction in the repeated measures ANOVA, intra-group comparisons were assessed using the Tukey–Kramer method and inter-group comparisons at each time point were evaluated using unpaired *t*-tests ($P < 0.05$). In addition, group differences in changes from week 0 to week 24 and in values at week 36 were analyzed using unpaired *t*-tests ($P < 0.05$). The relationship between the initial value and the change from week 0 to week 24 (i.e., week 24–week 0) was investigated using Pearson's correlation coefficient. All statistical analyses were performed using StatView for Windows version 5.0 (SAS Institute, Cary, NC). Values presented are means ± s.e.

RESULTS

Study population

Participant flow during the study period is shown in **Figure 2**.

Forty-four subjects were enrolled, but two subjects dropped out during the lead-in period; the remaining forty-two subjects

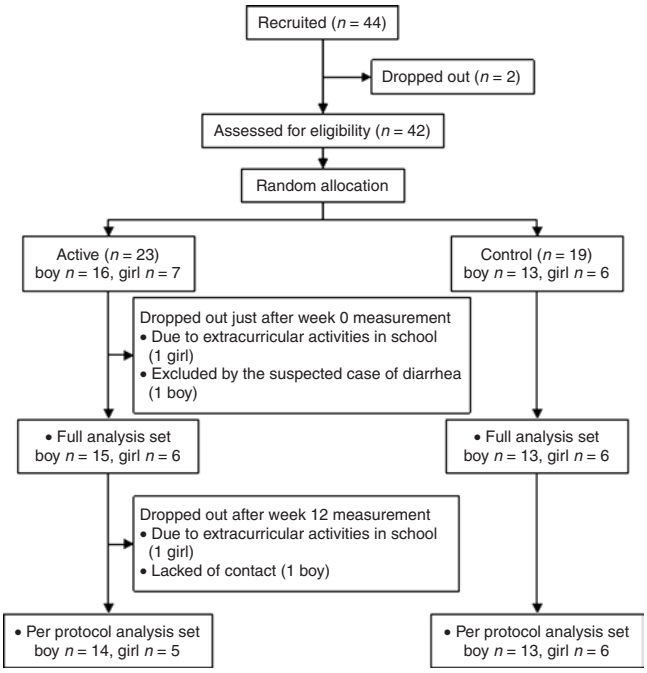

Figure 2 Participant flow.

were assigned to two groups (catechin group, n = 23; control group, n = 19). One girl and one boy in the catechin group dropped out after measurements at week 0 due to extracurricular activities in school and diarrhea of unknown cause, respectively. An additional boy and girl in the catechin group dropped out after measurements at week 12 due to extracurricular activities in school and lack of contact with study personnel, respectively. Consequently, 14 boys and 5 girls in the catechin group (mean age: 11.1 ± 0.5 years) and 13 boys and 6 girls in the control group (mean age: 11.8 ± 0.6 years) completed the study, and were deemed to be the subjects comprising the per protocol analysis set. Fifteen boys and six girls, including the children who dropped out after the week-12 measurement in the catechin group (mean age: 11.4 ± 0.5 years) and thirteen boys and six girls in the control group (mean age: 11.8 ± 0.6 years) were deemed the subjects comprising the full analysis set. There were two girls who had attained menarche in the control group comprising both analysis sets. Data of seven subjects comprising both analysis sets were missing as follows: one boy in the catechin group did not have a blood pressure measurement performed at week 36; one boy in the catechin group was missing Hs CRP or all hematologic parameters at all visits, in addition to missing all biochemical parameters at week 12, except PAI-1, leptin, and growth hormone; one boy in the catechin group was missing all biochemical and hematologic parameters, except triglyceride, T-cho, free fatty acids, total ketone bodies, and glucose, at all visits; one boy in the control group did not have his height measured at week 36 and therefore did not have BMI or obesity index values calculated at week 36; one boy in the control group was missing Hs CRP at week 36; one boy in the control group did not have any biochemical or hematologic parameters measured, except glucose, PAI-1, leptin, growth hormone, and Hs CRP, at week 12; and, one boy in the control group was missing Hs CRP at all visits and all hematologic parameters at week 12.

There were no significant differences in initial values between the per protocol analysis set and the full analysis set. Thus, the results of the full analysis set subjects are mainly reported here.

Effects of catechins ingestion on anthropometric parameters and blood pressure

The results of anthropometric and blood pressure measurements in the full analysis set are shown in **Table 2**.

There were no significant group differences in any measured parameter at week 0.

There was a significant time effect, but no significant group effect or group-by-time interaction, during the beverage ingestion period for height, body weight, and LBM. Height and LBM increased significantly from week 0 to weeks 12 and 24 in both groups; the increase from week 12 to week 24 also was significant. The increases in body weight from weeks 0 and 12 to week 24 were significant in both groups; the increase from week 0 to week 12 also was significant in the control group. There was a significant time effect, but no significant group effect or group-by-time interaction for BMI and hip circumference during the beverage ingestion period. The increases in BMI and hip circumference from week 0 to week 24 were significant in the control group, but not in the catechin group. There was a significant time effect, but no significant group effect or group-by-time interaction for body fat ratio during the beverage ingestion period. The decrease in body fat ratio from week 0 to week 24 were significant in the catechin group, but not in the control group. There were no significant changes in any other parameter during the beverage ingestion period. There were no significant group differences in any measured parameter at week 36.

Responses in anthropometric parameters and blood pressure to treatment within the per protocol analysis sample were not significantly different from those noted in the full analysis set (data not shown).

Effects of catechins ingestion on biochemical and hematologic parameters

The results of measurements of biochemical and hematologic parameters in the full analysis set are shown in **Tables 3** and **4**.

At week-0, PAI-1 was significantly lower in the catechin group compared with the control group, but there were no significant group differences in any other parameter at week 0.

There was a significant group-by-time interaction for the LDL-cho/HDL-cho during the beverage ingestion period, with a significant decrease at week 24 from week 0 in the catechin group and a significant difference between the two groups at week 24. At week 24, the change from week 0 in the ratio was significantly different between the two groups: −0.28 ± 0.11 in the catechin group and 0.15 ± 0.09 in the control group. There was a significant group-by-time interaction for free fatty acids during the beverage ingestion

Table 2 Changes in anthropometric and blood pressure after daily ingestion of either a catechin-rich beverage or a control beverage for 24-week

	n	0 Week	12 Week	24 Week	ΔValue at 24 week[a]	36 Week
Height*[b] (cm)						
Catechin	21	153.5 ± 2.9	154.7 ± 2.8A[c]	155.8 ± 2.7A,B[c]	2.3 ± 0.3	157.1 ± 2.7
Control	19	153.1 ± 2.7	154.4 ± 2.7A	155.5 ± 2.7A,B	2.4 ± 0.3	156.4 ± 2.6
Body weight* (kg)						
Catechin	21	65.5 ± 3.9	66.5 ± 3.7	67.7 ± 3.6A,B	2.2 ± 0.5	69.2 ± 3.5
Control	19	65.4 ± 3.9	67.3 ± 3.9A	68.8 ± 4.0A,B	3.4 ± 0.7	69.7 ± 3.9
BMI* (kg/m^2)						
Catechin	21	27.2 ± 0.8	27.3 ± 0.8	27.4 ± 0.7	0.2 ± 0.2	27.6 ± 0.7
Control	19	27.4 ± 0.9	27.8 ± 0.9	28.0 ± 0.9A	0.6 ± 0.2	28.1 ± 1.0
Obesity index (%)						
Catechin	21	43.9 ± 3.5	43.3 ± 3.3	43.4 ± 3.3	−0.5 ± 1.0	43.5 ± 3.3
Control	19	43.5 ± 4.5	44.4 ± 4.6	44.6 ± 4.5	1.1 ± 1.4	44.0 ± 4.6
Waist circumference (cm)						
Catechin	21	89.2 ± 2.4	89.0 ± 1.9	89.0 ± 2.0	−0.2 ± 1.0	89.5 ± 1.9
Control	19	88.9 ± 2.6	89.0 ± 2.8	90.3 ± 3.0	1.4 ± 0.9	89.6 ± 2.9
Hip circumference* (cm)						
Catechin	21	94.0 ± 2.3	94.6 ± 2.2	95.6 ± 2.2	1.6 ± 0.7	97.0 ± 2.1
Control	19	94.7 ± 2.5	96.0 ± 2.4	97.1 ± 2.3A	2.4 ± 0.6	96.2 ± 2.4
WHR						
Catechin	21	0.95 ± 0.01	0.94 ± 0.01	0.93 ± 0.02	−0.02 ± 0.01	0.92 ± 0.01
Control	19	0.94 ± 0.02	0.93 ± 0.02	0.93 ± 0.02	−0.01 ± 0.01	0.93 ± 0.02
LBM* (kg)						
Catechin	21	40.4 ± 2.6	41.1 ± 2.6A	42.2 ± 2.5A,B	1.9 ± 0.3	43.3 ± 2.5
Control	19	40.6 ± 2.3	41.9 ± 2.4A	43.0 ± 2.4A,B	2.4 ± 0.4	44.1 ± 2.4
BFM (kg)						
Catechin	21	24.5 ± 1.6	24.5 ± 1.4	24.4 ± 1.4	−0.1 ± 0.4	24.8 ± 1.3
Control	19	24.2 ± 1.7	24.7 ± 1.8	24.9 ± 1.8	0.7 ± 0.5	24.7 ± 1.8
BFR* (%)						
Catechin	21	37.1 ± 1.0	36.8 ± 1.0	36.1 ± 1.0A	−1.0 ± 0.4	35.9 ± 1.1
Control	19	36.3 ± 0.9	36.0 ± 1.1	35.6 ± 1.1	−0.6 ± 0.5	34.9 ± 1.2
VFA (cm^2)						
Catechin	21	55.4 ± 6.7		62.1 ± 6.2	6.7 ± 4.0	53.2 ± 6.2
Control	19	56.2 ± 9.9		61.3 ± 11.2	5.1 ± 4.9	63.1 ± 11.2
SFA (cm^2)						
Catechin	21	274.0 ± 19.5		284.0 ± 16.8	10.0 ± 6.0	287.4 ± 17.6
Control	19	265.2 ± 22.7		267.4 ± 26.0	2.1 ± 8.5	283.7 ± 26.7
SBP (mm Hg)						
Catechin	21	124.3 ± 2.9	121.9 ± 2.8	122.2 ± 2.8	−2.1 ± 3.5	120.0 ± 2.6
Control	19	120.5 ± 3.6	123.8 ± 3.7	128.3 ± 4.6	7.8 ± 4.1	124.0 ± 3.3
DBP (mm Hg)						
Catechin	21	63.2 ± 2.4	62.6 ± 2.8	66.0 ± 2.5	2.8 ± 2.7	64.8 ± 2.0
Control	19	64.8 ± 2.6	63.5 ± 2.3	65.4 ± 2.3	0.5 ± 2.6	66.9 ± 1.9

Values are means (±s.e.) of the full analysis set. All values including the number of subjects were corrected for missing data.
BFM, body fat mass; BFR, body fat ratio; DBP, diastolic blood pressure; LBM, lean body mass; SBP, systolic blood pressure; SFA, subcutaneous fat area; VFA, visceral fat area; WHR, waist-to-hip ratio.
[a]The value is the change from week 0 to week 24. [b]There was a significant time effect (*$P < 0.05$) in the repeated measures ANOVA during the beverage ingestion period.
[c]There was a significant difference from the week-0 value (A) or the week-12 value (B), as determined using Tukey–Kramer test during the beverage ingestion period.

Table 3 Changes in blood parameters after daily ingestion of either a catechin-rich beverage or a control beverage for 24-week

	n	0 Week	12 Week	24 Week	ΔValue at 24 week[a]	36 Week
Triglyceride (mmol/l)						
Catechin	21	1.18 ± 0.14	1.07 ± 0.14	1.28 ± 0.20	0.10 ± 0.18	1.16 ± 0.12
Control	19	1.25 ± 0.11	1.27 ± 0.13	1.38 ± 0.14	0.13 ± 0.12	1.30 ± 0.15
RLP-cho (mmol/l)						
Catechin	20	0.139 ± 0.015	0.133 ± 0.019	0.143 ± 0.025	0.004 ± 0.020	0.136 ± 0.013
Control	19	0.139 ± 0.013	0.145 ± 0.013	0.156 ± 0.014	0.017 ± 0.013	0.139 ± 0.017
T-cho (mmol/l)						
Catechin	21	4.79 ± 0.20	4.60 ± 0.19	4.56 ± 0.20	−0.23 ± 0.13	4.60 ± 0.20
Control	19	5.19 ± 0.30	5.16 ± 0.29	5.13 ± 0.29	−0.07 ± 0.14	5.02 ± 0.25
LDL-cho (mmol/l)						
Catechin	20	3.15 ± 0.18	2.95 ± 0.17	2.86 ± 0.16	−0.29 ± 0.13	2.95 ± 0.16
Control	19	3.52 ± 0.29	3.48 ± 0.28	3.51 ± 0.30	−0.01 ± 0.13	3.31 ± 0.25
HDL-cho (mmol/l)						
Catechin	20	1.26 ± 0.04	1.26 ± 0.04	1.29 ± 0.05	0.02 ± 0.04	1.23 ± 0.06
Control	19	1.30 ± 0.06	1.28 ± 0.06	1.25 ± 0.07	−0.04 ± 0.04	1.27 ± 0.07
LDL-cho/HDL-cho*[b]						
Catechin	20	2.52 ± 0.14	2.37 ± 0.12	2.25 ± 0.11A[c,**]	−0.28 ± 0.11***	2.45 ± 0.12
Control	19	2.83 ± 0.26	2.85 ± 0.27	2.98 ± 0.31	0.15 ± 0.09	2.75 ± 0.25
Free fatty acids (mmol/l)*						
Catechin	21	0.480 ± 0.058	0.440 ± 0.050	0.489 ± 0.042	0.009 ± 0.038	0.428 ± 0.046
Control	19	0.488 ± 0.045	0.542 ± 0.046	0.423 ± 0.042	−0.066 ± 0.041	0.502 ± 0.047
Total ketone bodies (μmol/l)						
Catechin	21	54.9 ± 11.6	68.1 ± 21.8	46.7 ± 8.4	−8.2 ± 9.3	51.1 ± 13.0
Control	19	48.5 ± 8.7	64.1 ± 13.2	43.5 ± 6.5	−5.0 ± 11.0	60.6 ± 12.6
Glucose (mmol/l)						
Catechin	21	5.03 ± 0.10	4.88 ± 0.06	4.92 ± 0.09	−0.11 ± 0.10	4.94 ± 0.10
Control	19	5.05 ± 0.09	5.01 ± 0.10	5.05 ± 0.12	0.00 ± 0.10	5.02 ± 0.14
PAI-1 (μg/l)						
Catechin	18	35.7 ± 2.7**[d]		37.8 ± 3.3	2.2 ± 3.3	33.0 ± 2.7
Control	19	50.6 ± 5.6		43.7 ± 4.5	−6.9 ± 4.6	40.2 ± 4.4
Leptin (μg/l)						
Catechin	18	19.0 ± 1.9		17.3 ± 2.0	−1.8 ± 1.9	17.2 ± 2.4
Control	19	19.6 ± 1.6		21.4 ± 2.6	1.8 ± 1.9	16.7 ± 1.7
Growth hormone (μg/l)						
Catechin	18	1.61 ± 0.71		0.96 ± 0.47	−0.36 ± 0.41	1.24 ± 0.63
Control	19	0.64 ± 0.24		1.30 ± 0.60	1.28 ± 0.77	1.92 ± 0.80
Hs CRP (μg/l)						
Catechin	17	1,730.4 ± 865.4		3,323.4 ± 2,455.1	1,592.9 ± 2,642.5	9,084.4 ± 7,953.6
Control	18	1,727.9 ± 463.5		2,136.1 ± 407.9	408.2 ± 402.1	2,033.3 ± 459.7

Values are means (±s.e.) of the full analysis set. All values including the number of subjects were corrected for missing data.
HDL-cho, high-density lipoprotein cholesterol; Hs CRP, high-sensitive C-reactive protein; LDL-cho, low-density lipoprotein cholesterol; LDL-cho/HDL-cho, low-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio; PAI-1, total plasminogen activator inhibitor-1; RLP-cho, remnant-like lipoprotein particles cholesterol; T-cho, total cholesterol.
[a]The value is the change from week 0 to week 24. [b]There was a significant group-by-time interaction (*$P < 0.05$) in the repeated measures ANOVA during the beverage ingestion period. [c]There was a significant difference from the week-0 value (A), as determined using Tukey–Kramer test, during the beverage ingestion period. [d]There was a significant difference between the groups, as determined using an unpaired *t*-test (two-sided, **$P < 0.05$, ***$P < 0.01$).

Table 4 Changes in blood parameters after daily ingestion of either a catechin-rich beverage or a control beverage for 24-week

	n	0 Week	12 Week	24 Week	ΔValue at 24 week[a]	36 Week
ALP**[b] (U/l)						
Catechin	20	897.9 ± 86.7	894.7 ± 86.1	855.8 ± 87.0	−42.1 ± 42.6	872.7 ± 95.1
Control	19	823.3 ± 87.8	849.7 ± 99.0	766.8 ± 83.5B[c]	−56.5 ± 33.2	788.4 ± 99.6
LDH*[b] (U/l)						
Catechin	20	234.5 ± 8.3	223.5 ± 8.6	221.1 ± 7.9	−13.4 ± 6.5	225.7 ± 10.6
Control	19	218.8 ± 8.9	234.2 ± 13.7	221.2 ± 9.7	2.4 ± 4.2	222.5 ± 9.5
γ-GTP (U/l)						
Catechin	20	22.5 ± 2.1	21.6 ± 2.0	22.7 ± 2.3	0.2 ± 1.6	22.9 ± 2.6
Control	19	22.4 ± 2.4	22.6 ± 2.5	24.9 ± 3.7	2.6 ± 1.7	23.7 ± 3.7
AST (U/l)						
Catechin	20	29.0 ± 3.0	26.4 ± 2.5	25.3 ± 1.7	−3.8 ± 2.2	25.9 ± 2.4
Control	19	23.6 ± 1.7	24.3 ± 2.0	23.0 ± 1.7	−0.6 ± 1.4	23.2 ± 1.7
ALT (U/l)						
Catechin	20	38.5 ± 7.6	33.7 ± 5.4	32.2 ± 4.6	−6.3 ± 5.1	33.4 ± 5.8
Control	19	29.4 ± 4.3	28.9 ± 4.8	28.7 ± 4.5	−0.7 ± 2.9	28.1 ± 4.2
Creatinine** (μmol/l)						
Catechin	20	46.6 ± 2.1	48.6 ± 2.5	49.5 ± 2.9A[c]	2.9 ± 1.2	50.1 ± 3.0
Control	19	47.3 ± 2.1	49.1 ± 2.2	49.6 ± 2.1A	2.3 ± 0.9	51.7 ± 2.2
Uric acid (μmol/l)						
Catechin	20	380.7 ± 24.0	367.9 ± 18.1	363.7 ± 19.7	−17.0 ± 14.2	357.8 ± 18.9
Control	19	373.2 ± 15.8	375.7 ± 14.2	380.0 ± 18.9	6.9 ± 13.8	376.3 ± 16.5
Urea nitrogen (μmol/l)						
Catechin	20	4.19 ± 0.24	4.16 ± 0.31	4.00 ± 0.25	−0.19 ± 0.21	4.14 ± 0.22
Control	19	4.14 ± 0.17	4.17 ± 0.28	4.13 ± 0.21	−0.02 ± 0.17	4.45 ± 0.24
Total protein (g/l)						
Catechin	20	75.5 ± 0.8	74.7 ± 0.9	74.6 ± 0.8	−0.9 ± 0.8	73.9 ± 0.9
Control	19	75.5 ± 1.0	75.2 ± 1.0	75.8 ± 1.0	0.3 ± 0.7	75.7 ± 1.2
Albumin (g/l)						
Catechin	20	46.1 ± 0.6	45.7 ± 0.5	46.0 ± 0.4	−0.1 ± 0.5	45.3 ± 0.6
Control	19	47.0 ± 0.6	46.5 ± 0.6	46.6 ± 0.5	−0.4 ± 0.5	46.8 ± 0.7
Inorganic phosphate (mmol/l)						
Catechin	20	1.48 ± 0.05	1.48 ± 0.04	1.52 ± 0.04	0.04 ± 0.04	1.43 ± 0.05
Control	19	1.49 ± 0.04	1.47 ± 0.04	1.45 ± 0.04	−0.04 ± 0.04	1.47 ± 0.04
Calcium (mmol/l)						
Catechin	20	2.45 ± 0.02	2.44 ± 0.02	2.44 ± 0.02	−0.02 ± 0.02	2.41 ± 0.02
Control	19	2.48 ± 0.02	2.45 ± 0.02	2.45 ± 0.02	−0.03 ± 0.02	2.47 ± 0.02
Iron (μmol/l)						
Catechin	20	16.3 ± 1.0	16.9 ± 1.5	16.4 ± 1.1	0.1 ± 1.6	15.6 ± 1.2
Control	19	15.7 ± 1.3	16.2 ± 1.6	14.2 ± 1.1	−1.5 ± 1.3	16.0 ± 1.5
Magnesium (mmol/l)						
Catechin	20	0.94 ± 0.02	0.94 ± 0.01	0.95 ± 0.02	0.01 ± 0.01	0.92 ± 0.01
Control	19	0.93 ± 0.01	0.93 ± 0.01	0.91 ± 0.02	−0.02 ± 0.01	0.92 ± 0.01
Sodium (mmol/l)						
Catechin	20	140.2 ± 0.3	140.2 ± 0.3	140.0 ± 0.4	−0.2 ± 0.3	140.0 ± 0.4

Table 4 continued on next page

Table 4 Changes in blood parameters after daily ingestion of either a catechin-rich beverage or a control beverage for 24-week (continued)

	n	0 Week	12 Week	24 Week	ΔValue at 24 week[a]	36 Week
Control	19	139.5 ± 0.3	140.2 ± 0.5	140.3 ± 0.3	0.8 ± 0.4	140.2 ± 0.4
Potassium** (mmol/l)						
Catechin	20	4.8 ± 0.1	4.5 ± 0.1	4.6 ± 0.1	−0.2 ± 0.1	4.5 ± 0.1
Control	19	4.7 ± 0.1	4.4 ± 0.1A	4.4 ± 0.0A	−0.3 ± 0.1	4.4 ± 0.1
Chloride (mmol/l)						
Catechin	20	102.5 ± 0.5	103.3 ± 0.5	102.7 ± 0.5	0.2 ± 0.6	103.0 ± 0.4
Control	19	101.9 ± 0.4	102.8 ± 0.5	102.8 ± 0.4	0.9 ± 0.4	102.8 ± 0.5
WBC ($\times 10^6$/l)						
Catechin	19	6,500.0 ± 310.1	6,873.7 ± 384.1	7,042.1 ± 413.2	542.1 ± 448.1	7,147.4 ± 421.8
Control	19	7,410.5 ± 460.6	7,626.3 ± 609.5	7,831.6 ± 418.6	421.1 ± 379.6	7,942.1 ± 537.2
RBC** ($\times 10^{10}$/l)						
Catechin	19	492.7 ± 7.4	489.7 ± 7.6	496.7 ± 8.7	4.1 ± 4.7	492.9 ± 8.5
Control	19	490.2 ± 7.6	486.5 ± 6.5	496.9 ± 7.3B	6.7 ± 3.6	498.6 ± 7.6
Hemoglobin** (g/l)						
Catechin	19	138.7 ± 2.0	138.1 ± 2.2	140.0 ± 2.4	1.3 ± 1.3	140.0 ± 2.5
Control	19	136.6 ± 2.2	136.1 ± 1.7	139.7 ± 2.1B	3.1 ± 1.1	139.8 ± 2.1
Hematocrit** (%)						
Catechin	19	41.86 ± 0.56	42.06 ± 0.60	42.99 ± 0.69A,B	1.13 ± 0.43	42.86 ± 0.64
Control	19	41.35 ± 0.58	41.31 ± 0.47	42.65 ± 0.54A,B	1.31 ± 0.36	42.93 ± 0.54
Platelet count ($\times 10^{10}$/l)						
Catechin	19	29.93 ± 1.57	29.81 ± 1.41	29.24 ± 1.44	−0.69 ± 0.78	29.44 ± 1.45
Control	19	32.57 ± 1.48	32.25 ± 1.27	33.05 ± 1.57	0.48 ± 0.77	33.28 ± 1.44

Values are means (±s.e.) of the full analysis set. All values including the number of subjects were corrected for missing data.
γ-GTP, γ-glutamyl transpeptidase; ALP, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; LDH, lactate dehydrogenase; RBC, red blood cell count; WBC, white blood cell count.
[a]The value is the change from week 0 to week 24. [b]There was a significant group-by-time interaction (*$P < 0.05$) and a significant time effect (**$P < 0.05$) in the repeated measures ANOVA during the beverage ingestion period. [c]There was a significant difference from the week-0 value (A) or the week-12 value (B), as determined using Tukey–Kramer test during the beverage ingestion period.

period, but the value did not change significantly in either group. There was a significant time effect for alkaline phosphatase during the beverage ingestion period, with a significant decrease in the control group from week 12 to week 24. There was a significant group-by-time interaction for lactate dehydrogenase during the beverage ingestion period, but the value did not change significantly in either group. There was a significant time effect for creatinine during the beverage ingestion period due to a significant increase from week 0 to week 24 in both groups. There was a time effect for potassium during the beverage ingestion period, with a significant decrease from week 0 to weeks 12 and 24 in the control group. There was a significant time effect for red blood cell count and hemoglobin during the beverage ingestion period, with a significant increase in the control group from week 12 to week 24. There was a significant time effect for hematocrit during the beverage ingestion period, with a significant increase at week 24 from weeks 0 to 12 in both groups. There were no significant changes in any other parameter during the beverage ingestion period. There were no significant group differences in any measured parameter at week 36.

Responses in biochemical and hematologic parameters to treatment within the per protocol analysis sample were not significantly different from those noted in the full analysis set (data not shown).

Urinalysis, daily living record, and interview

There were no significant differences in any parameter examined in the urinalysis (data not shown).

In the subject belonging to the catechin group who dropped out of the study after the week-0 examination due to diarrhea, the physician concluded that there was no causal relationship between ingestion of the test beverage and occurrence of diarrhea, because diarrhea frequently occurs in children. No other adverse events attributable to the test beverage were observed.

On the basis of the subject interviews and daily living records, the subjects maintained their usual diet and exercise habits, drank the test beverage according to the protocol, and did not consume any of the prohibited foods or beverages.

Table 5 Relations between the values at week 0 and the changes from week 0 to week 24 in measures of the metabolic syndrome related parameters

	Catechin			Control		
	n	*R*[a]	*P* value[b]	*n*	*R*	*P* value
BMI	21	−0.525	0.0134	19	−0.080	0.7474
Obesity index	21	−0.362	0.1075	19	−0.159	0.5223
Waist circumference	21	−0.578	0.0052	19	0.331	0.1688
Hip circumference	21	−0.349	0.1217	19	−0.370	0.1199
WHR	21	−0.087	0.7098	19	0.451	0.0653
LBM	21	−0.233	0.3135	19	0.133	0.5922
BFM	21	−0.593	0.0038	19	0.058	0.8176
BFR	21	−0.044	0.8528	19	0.047	0.8505
VFA	21	−0.418	0.0588	19	0.023	0.9267
SFA	21	−0.570	0.0060	19	0.232	0.3439
SBP	21	−0.617	0.0023	19	−0.313	0.1951
DBP	21	−0.529	0.0125	19	−0.602	0.0053
Triglyceride	21	−0.216	0.3513	19	−0.309	0.2016
RLP-cho	20	0.048	0.8438	19	−0.398	0.0922
T-cho	21	−0.277	0.2276	19	−0.292	0.2292
LDL-cho	20	−0.489	0.0273	19	−0.181	0.4644
HDL-cho	20	−0.365	0.1141	19	−0.095	0.7027
LDL-cho/HDL-cho	20	−0.618	0.0029	19	0.477	0.0380
Glucose	21	−0.599	0.0033	19	−0.255	0.2966

BFM, body fat mass; BFR, body fat ratio; DBP, diastolic blood pressure; HDL-cho, high-density lipoprotein cholesterol; LBM, lean body mass; LDL-cho, low-density lipoprotein cholesterol; LDL-cho/HDL-cho, low-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio; RLP-cho, remnant-like lipoprotein particles cholesterol; SBP, systolic blood pressure; SFA, subcutaneous fat area; T-cho, total cholesterol; VFA, visceral fat area; WHR, waist-to-hip ratio.
[a]Values are Pearson's correlation coefficients. All values including the number of subjects were corrected for missing data. [b]Values are the *P* values after Fisher *r*-to-*z* transformation.

Correlations between week-0 values and differences between week 24 and week 0 values

Correlations between the initial values and the differences from week 0 to week 24 for the main outcome variables—risk factors for lifestyle-related disorders—were examined using the full analysis set values (Table 5).

There were no significant correlations for BMI, waist circumference, BFM, SFA, SBP, LDL-cho, or glucose in the control group. There were, however, significant negative correlations for these parameters in the catechin group. There was a significant negative correlation for DBP in both groups. There was a positive correlation for the LDL-cho/HDL-cho in the control group, but a negative correlation in the catechin group.

Analysis stratified by median values at week 0

For the parameters that exhibited significant correlations between initial values and change in the catechin group, such as BMI, waist circumference, BFM, SFA, SBP, LDL-cho, and glucose, changes at week 24 in those parameters were compared between the two groups after stratifying by the median week-0 values for each parameter (Table 6).

There were no significant differences in the week-0 values between the two groups for any of the parameters examined for either the above- or below-median categories. In the below-median category, there were no significant group differences in the change from week 0 to week 24 in any parameter. For the above-median category, the decreases in waist circumference, SBP, and LDL-cho, from week 0 to week 24 were significantly greater in the catechin group compared with the control group.

DISCUSSION

The effect of a catechin-rich beverage on body fat and risk factors associated with the metabolic syndrome and the safety of 24-week daily ingestion of the beverage were investigated in obese or near-obese Japanese children in a double-blind parallel group intervention study. In the full analysis set subjects, there were no significant differences in the major outcome variables, such as anthropometrics, blood pressure, and systemic risk factors of the metabolic syndrome, between the catechin and the control groups. Although there were no significant group differences for LDL-cho or HDL-cho, there was a significant group-by-time interaction for the LDL-cho/HDL-cho; the decrease at week 24 was significantly greater in the catechin group compared with the control group. This result suggests that daily ingestion of the catechin-rich beverage improved blood cholesterol levels in obese and near-obese children. Furthermore, in the catechin group at week 24, the initial values and changes in BMI, waist circumference, BFM, SFA, SBP, LDL-cho, glucose, and LDL-cho/HDL-cho were negatively correlated. In the analysis stratified by the median of the week-0 values, the decrease at week 24 in waist circumference, SBP, and LDL-cho in the catechin group was significantly greater than that in control group for subjects in the above-median category. These findings suggest that daily ingestion of the catechin-rich beverage effectively reduced waist circumference, SBP, and LDL-cho in subjects with initially high values of these parameters.

In adults, ingestion of a catechin-rich beverage for 12 weeks reduced abdominal fat area, SBP, and LDL-cho (12). In this study, however, the effects of the catechin-rich beverage on these parameters were very weak compared to the magnitude of the effects in adults—even though the ingestion period was twice as long in this study. Teramoto *et al.* assessed body composition using bioelectric impedance analysis in Japanese children aged 3–6 years, and noted that BFM was positively correlated with age in both boys and girls (19). Huang *et al.* calculated VFA and SFA in children at multiple time points and found that VFA increased at a rate of 5.2 ± 2.2 cm^2/years and SFA at 8.8 ± 4.9 cm^2/years (20). Furthermore, growth of children spurts during puberty, height velocity in low teenage varies widely (21), and the standard divisions of height and body weight are shown to increase in children of 6–14 years old (1). Thus, failure of detections in anthropometric parameter changes in children of this study may be due to the

Table 6 Changes in the parameters with significant correlations between the week 0 values and the changes from week 0 to week 24, stratified by the median of the week 0 value

			Below-median category			Above-median category		
	Median at 0 week		*n*	0 Week	ΔValue at 24 week[a]	*n*	0 week	ΔValue at 24 week
BMI (kg/m^2)	26.2	Catechin	10	24.5 ± 0.5	0.7 ± 0.2	11	29.7 ± 1.1	−0.2 ± 0.2
		Control	8	23.8 ± 0.5	0.9 ± 0.4	11	30.0 ± 1.0	0.4 ± 0.3
Waist circumference (cm)	87.5	Catechin	13	82.1 ± 1.4	1.5 ± 1.0	8	100.7 ± 2.9	−2.9 ± 1.8*[b]
		Control	7	78.0 ± 2.8	0.3 ± 1.4	12	95.3 ± 2.3	2.1 ± 1.2
BFM (kg)	22.1	Catechin	10	19.4 ± 1.0	0.7 ± 0.4	11	29.1 ± 2.0	−0.8 ± 0.7
		Control	10	19.0 ± 1.0	0.7 ± 0.7	9	30.0 ± 2.3	0.7 ± 0.6
SFA (cm^2)	248.2	Catechin	11	209.4 ± 9.3	22.4 ± 7.2	10	345.0 ± 24.6	−3.7 ±8.1
		Control	9	191.6 ± 13.2	10.7 ± 10.3	10	331.5 ± 28.2	−5.5 ± 13.3
SBP (mm Hg)	119.0	Catechin	8	112.3 ± 1.6	11.1 ± 4.1	13	131.7 ± 3.1	−10.2 ± 3.4*
		Control	12	110.2 ± 2.0	9.5 ± 5.6	7	138.1 ± 3.8	5.0 ± 6.3
LDL-cho (mmol/l)	3.08	Catechin	10	2.60 ± 0.07	0.10 ± 0.14	10	3.71 ± 0.26	−0.68 ± 0.13*
		Control	9	2.65 ± 0.10	0.11 ± 0.14	10	4.31 ± 0.41	−0.12 ± 0.21
Glucose (mmol/l)	5.00	Catechin	10	4.69 ± 0.06	0.10 ± 0.12	11	5.34 ± 0.13	−0.30 ± 0.14
		Control	8	4.71 ± 0.08	0.12 ± 0.09	11	5.30 ± 0.08	−0.09 ± 0.16

Values are means (±s.e.) of the full analysis set. All values including the number of subjects were corrected for missing data.
BFM, body fat mass; LDL-cho, low-density lipoprotein cholesterol; SFA, subcutaneous fat area; SBP, systolic blood pressure.
[a]The value is the change from week 0 to week 24. [b]There was a significant difference between the groups, as determined using an unpaired *t*-test (two-sided, $^*P < 0.05$).

accumulation of body fat with growth and the difference of growth rate in individual subjects. It may also be due to the characteristics in abdominal fat distribution of children. In the adult study (12), initial waist circumference was ~89 cm—approaching the criteria for the metabolic syndrome in Japanese adults (85 cm in men and 90 cm in women). A waist circumference of 89 cm in adults is equivalent to a VFA of ~100 cm^2 (22). In this study, the initial VFA in all subjects was 55.8 ± 5.8 cm^2 (n = 40), about half the value expected from the adult waist circumference data. The VFA to SFA ratio was ~0.2 (n = 40), which was less than the criterion for visceral fat-type obesity (0.4), indicating that the subjects in this study were in the state of subcutaneous fat-type obesity. In the report by Huang *et al.* described earlier, the rate of SFA accumulation was greater than the rate of VFA accumulation in children (20). In addition, the VFA and SFA values in this study were similar to the values reported by Asayama *et al.* (23), who observed that, in children, SFA accumulates more easily than VFA. Because catechins are thought to reduce VFA primarily by promoting β-oxidation in the liver (9), it is also possible that the effect of catechins on abdominal fat is not apparent in children who have very small VFA. Taken together, increase of body fat with growth, wide dispersion of individual growth rate during puberty, and low value of initial VFA might be the reasons that we could not detect clear effects of catechins in anthropometric parameters in this study.

The lack of puberty assessment and small sample size were limitations of this study. Because growth rate of children during puberty varies greatly, a larger number of subjects and/or classification of the study population according to Tanner stage would have helped us to draw more clear effects of catechins.

A primary objective of this study was to investigate the safety of daily ingestion of the catechin-rich beverage in children. Because there were no significant group differences either in height or in LBM, daily ingestion of the catechin-rich beverage did not appear to affect growth in children. In the control group, alkaline phosphatase decreased and red blood cell count and hemoglobin increased over the duration of the study. For the catechin group, changes in these parameters showed the same trends, but they were not statistically significant. In both groups, creatinine and hematocrit increased during the study; although the changes were not statistically significant in the intra-group analysis. This may have been due to growth of the subjects. The control group exhibited a small, but statistically significant decrease in serum potassium. Because potassium values remained in the normal range and there were no significant changes in sodium, it is unlikely that the catechin-rich beverage affected serum electrolytes. There was a group-by-time interaction for free fatty acids and lactate dehydrogenase, but there were no significant differences between the intra-group and the inter-group analyses. Although the changes in these parameters were small, there were transient decrease or increase at week 12 showing no persistent trends. Thus, it was concluded that the group-by-time interactions were not caused by the test beverage. Therefore, ingestion of the catechin-rich beverage did not appear to affect the measured safety parameters in children.

In conclusion, the results of this study suggest that daily ingestion of a catechin-enriched green tea beverage effectively

improves serious obesity and reduces cardiovascular disease risk factors in obese children. The magnitude of the beneficial effects in children were not as great as those observed in adults, possibly due to increase of body fat with growth, wide dispersion of individual growth rate during puberty, and low value of initial VFA. Measured safety parameters were unaffected by catechins consumption; therefore, the results did not raise any safety concerns regarding daily ingestion of a catechin-rich beverage in children.

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DISCLOSURE

The authors declared no conflict of interest.

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