

Research Article



Effects of consuming foods containing rosehip-derived tiliroside on abdominal visceral fat: A randomized, double-blind, placebo-controlled, parallel-group trial

Nana Norikami¹, Akifumi Nagatomo¹, Mamiko Kohno^{1*}, Naoko Suzuki², and Tsuyoshi Takara³

¹Morishita Jintan Co., Ltd., Hirakata, Osaka, 573-0128, Japan; ²ORTHOMEDICO Inc., Bunkyo-ku, Tokyo, 112-0002, Japan;

³Medical Corporation Seishinkai, Takara Clinic, Shinagawa-ku, Tokyo, 141-0022, Japan.

***Corresponding author:** Mamiko Kohno, Morishita Jintan Co., Ltd. 2-11-1, Tsudayamate, Hirakata, Osaka, 573-0128, Japan.

Email: m_kohno@jintan.co.jp

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Abstract

Background: Tiliroside, an acylated flavonol glycoside found in rosehips, has been reported to reduce abdominal total and visceral fat areas in preobese individuals, but the evidence is limited.

Objectives: This study aimed to investigate the effect of daily consumption of foods containing rosehip-derived tiliroside on abdominal visceral fat in overweight Japanese adults.

Methods: This was a randomized, double-blind, placebo-controlled, parallel-group clinical trial conducted from October 31, 2023, to April 30, 2024. Participants were randomly assigned to either a rosehip group (receiving 100 mg/day of rosehip extract containing 0.1% tiliroside) or a placebo group (50 participants per group). Outcome measures included abdominal total fat area (TFA), abdominal visceral fat area (VFA), abdominal subcutaneous fat area (SFA), body weight, body mass index (BMI), body fat percentage, fat mass, lean mass, muscle mass, waist circumference, and a dietary survey. The primary outcome was abdominal VFA after the 12-week intervention.

Results: For abdominal fat outcomes, the analysis included 47 participants in the rosehip group and 46 in the placebo

group; body-composition outcomes were analyzed in 48 and 49 participants, respectively. After 12 weeks, abdominal VFA was significantly reduced in the rosehip group compared with the placebo group. In an exploratory subgroup analysis of participants with baseline VFA < 100 cm², a similar between-group difference was observed. At week 4, the rosehip group showed significantly lower body fat percentage and fat mass and significantly higher lean mass and muscle mass than the placebo group. No significant differences between groups were observed in the subgroup analysis for body composition outcomes.

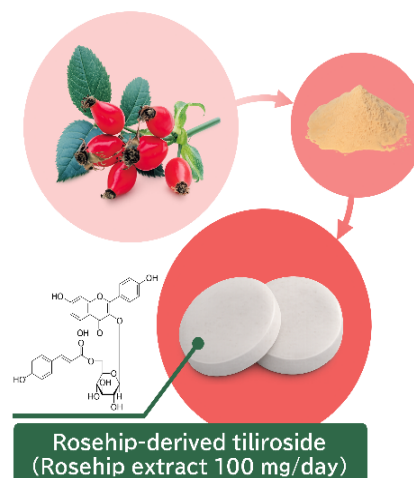
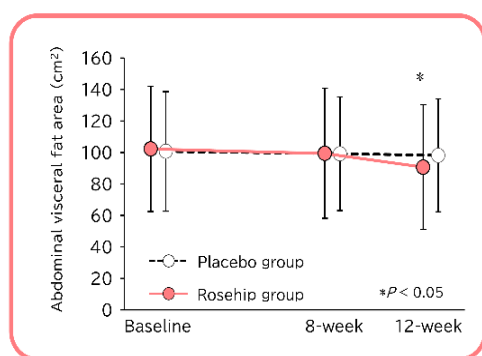
Conclusion: These findings suggest that consuming foods containing rosehip-derived tiliroside may reduce abdominal VFA. The observed week-4 differences in body-composition outcomes should be interpreted as exploratory secondary findings.

Novelty of the Study: This study provides additional clinical evidence of the visceral fat-reducing effect of rosehip-derived tiliroside in overweight Japanese individuals (BMI ≥ 25 and < 30 kg/m²). Designed based on a priori sample size estimation from previous findings and with abdominal VFA specified as the primary outcome, the present trial strengthens the reliability of the evidence supporting the potential effect of rosehip-derived tiliroside on abdominal fat management.

Trial Registration: UMIN000052587

Keywords: Rosehip-derived tiliroside; abdominal visceral fat; visceral adiposity; overweight adults; randomized controlled trial; functional foods

Foods containing rosehip-derived tiliroside reduce abdominal visceral fat area



Graphical Abstract. Effects of rosehip-derived tiliroside on abdominal visceral fat.

INTRODUCTION

The prevalence of overweight and obesity is increasing globally due to a decline in physical activity driven by economic growth and rapid urbanization, coupled with an increased intake of high-calorie processed foods [1-2]. According to the World Health Organization, 43% of adults aged ≥ 18 years were overweight ($\text{BMI} \geq 25$ and $< 30 \text{ kg/m}^2$), including 16% who were living with obesity (body mass index [BMI] $\geq 30 \text{ kg/m}^2$), and the global prevalence of adult obesity more than doubled between 1990 and 2022 [3]. In Japan, according to the results of the 2023 National Health and Nutrition Survey, 31.5% of men and 21.1% of women aged ≥ 20 years were classified as overweight or obese ($\text{BMI} \geq 25 \text{ kg/m}^2$) [4].

Asian populations, including the Japanese, are known to be more prone to accumulating abdominal visceral fat than other ethnic groups [5]. Several studies have confirmed that abdominal visceral fat accumulation is a major risk factor for health conditions such as impaired glucose tolerance, dyslipidemia, and hypertension [6-7]. Visceral obesity is associated with a higher risk of metabolic disorders and atherosclerotic cardiovascular diseases compared with subcutaneous obesity [6], and the abdominal visceral fat area (VFA) is positively correlated with the number of cardiovascular risk factors [8]. A cohort study of Japanese Americans reported that abdominal VFA, along with BMI and waist circumference, was positively correlated with the risk of type 2 diabetes [9]. Furthermore, when abdominal VFA exceeds 100 cm^2 , the average number of cardiovascular risk factors exceeds 1.0 in both men and women [8]. Therefore, reducing VFA is a crucial approach to preventing obesity-related diseases.

“Rosehip” is a generic term for the fruits of plants in the Rosaceae family, which contain vitamins, phenolic acids, tannins, and flavonoids [10]. In Europe, rosehips have

traditionally been used as laxatives, diuretics, and anti-gout and antirheumatic agents [10-11]. Recent studies have confirmed that rosehip extracts derived from the dog rose (*Rosa canina*) have anti-obesity effects [10,12]. These anti-obesity effects have been consistently demonstrated in *in vitro* and *in vivo* studies, as well as in human clinical trials [10, 12-13], and are thought to be driven by the action of tiliroside, a type of polyphenol found in the seeds [12]. Thus, foods containing rosehip-derived tiliroside can be classified as products utilizing scientifically validated health claims to support the maintenance and promotion of health [14-17]. Similarly, other functional food ingredients, such as vine tea extract and bitter melon-based multi-herbal extracts, have also been reported to support health claims [18-19]. Indeed, our previous study found that continuous intake of 100 mg/day of rosehip extract containing 0.1% tiliroside for 12 weeks significantly reduced abdominal total fat area (TFA), abdominal VFA, body weight, and BMI in healthy Japanese individuals with a $\text{BMI} \geq 25$ and $< 30 \text{ kg/m}^2$ compared with a placebo group [20]. However, our previous study had limitations, as it lacked a sample size justification and did not adjust for multiple comparisons across outcomes [20]. Consequently, we deemed it necessary to conduct a trial with a sample size calculated based on the results of our previous study to increase the certainty of the evidence that foods containing rosehip-derived tiliroside reduce abdominal VFA.

In the present study, VFA was defined as the primary outcome, and the effects of consuming a dietary supplement containing rosehip extract (100 mg/day, containing 0.1% tiliroside) on VFA were evaluated in healthy Japanese individuals with a $\text{BMI} \geq 25$ and $< 30 \text{ kg/m}^2$. Additionally, the required number of participants was calculated based on the results of the previous study [20], and chronic constipation—which can affect VFA

measurements—was added as a new exclusion criterion.

MATERIALS AND METHODS

Study design, ethical statement, participant recruitment and eligibility criteria:

This was a randomized, double-blind, placebo-controlled, parallel-group trial, stratified by sex (male, female) and age (≥ 40 years, < 40 years), with a 1:1 allocation ratio between the groups. The study was approved by the Institutional Review Board of the Medical Corporation Seishinkai, Takara Clinic (approval date: October 18, 2023; approval number: 2310-00187-0037-OC-TC) and registered in the UMIN-CTR (registration number: [UMIN000052587](https://www.umin.ac.jp/ctr/show/000052587)). Furthermore, the study was conducted in accordance with the principles of the Declaration of Helsinki and the Ethical Guidelines for Research Involving Human Subjects in the Life Sciences and Medicine, with due consideration for medical ethics.

Study participants were recruited online by ORTHOMEDICO Inc. (Tokyo, Japan) via their website (<https://www.go106.jp/>). Detailed explanations of the study's content were provided online, and participants provided informed consent electronically. Following ethics committee approval on October 18, 2023, participant recruitment took place from October 24 to December 25, 2023. The clinical trial was conducted from October 31, 2023, to April 30, 2024.

The inclusion criteria for this study were healthy Japanese individuals aged ≥ 18 years with a BMI ≥ 25 and < 30 kg/m². The primary exclusion criteria were as follows: (1) a history of, or current, serious disease affecting the heart, liver, kidneys, digestive system, or other organs; (2) an implanted pacemaker or implantable cardioverter-defibrillator; (3) current treatment for chronic conditions such as arrhythmia, liver dysfunction, chronic kidney disease, cerebrovascular disorders, rheumatic diseases, diabetes, dyslipidemia, or hypertension; (4) current use of medications, herbal medicines, or health supplements; (5)

drug or food allergies, particularly to the test foods used in this study; (6) excessive tobacco or alcohol consumption; (7) plans for shift work, relocation, or extended business or leisure travel during the trial period; (8) irregular dietary habits; (9) current dieting or exercising aimed at muscle gain; (10) anticipated significant changes in exercise habits during the study period; (11) a diagnosis of chronic constipation; (12) pregnancy, breastfeeding, or plans to become pregnant during the study period; and (13) participation in another clinical trial within 28 days prior to providing informed consent, or plans to participate in another clinical trial during the study period. For detailed eligibility criteria, please refer to the UMIN-CTR registration. During the planning phase of this study, no provisions were made to incorporate the perspectives of the general public and patients regarding the functionality of rosehip-derived tiliroside. Participants were instructed to avoid overeating and heavy alcohol consumption and to maintain their usual lifestyle habits throughout the study. From the day before each examination until completion of the examination, participants were required to refrain from alcohol consumption and strenuous exercise. To standardize hydration status and minimize measurement variability in the bioelectrical impedance analysis (BIA) using a multifrequency body composition analyzer, they were also instructed to refrain from eating and drinking for at least 6 h before blood collection and body composition assessment, including consumption of the test food, with only water permitted. Exercise specifically intended for weight loss or muscle gain and substantial changes in habitual physical activity were prohibited during the study period. Water intake was not restricted or recorded.

Sample size: The target sample size was determined based on the reduction in abdominal VFA observed following rosehip extract intake in a previous study [20]. To detect a significant difference in VFA at 12 weeks, the required

minimum sample size was calculated as 40 participants per group. This calculation assumed a mean difference and standard deviation derived from the previous findings, maintaining a two-sided significance level (α) of 5% and a statistical power ($1-\beta$) of 90%. Considering an anticipated attrition rate of over 10% due to factors such as post-enrollment ineligibility or withdrawal of consent, the final enrollment goal was set at 45 participants per group, for a total of 90 participants.

Selection, randomization, and blinding: Morishita Jintan Co., Ltd. (MJ; Osaka, Japan), the study sponsor and funder, labeled or printed identification numbers on the test foods and provided the products to the contract research organization (CRO). MJ securely stored the details of these identification numbers (indicating whether the product contained rosehip extract or placebo) and did not disclose them to any other organization or individual until the

allocation officer submitted the allocation table after the study concluded. The allocation officer, who was not directly involved in the study, randomly assigned 50 participants to the rosehip group and 50 to the placebo group based on a computer-generated randomization list, stratified by sex (male, female) and age (≥ 40 years, < 40 years). The allocation table was provided exclusively to the CRO's test food shipping team, who then distributed the test foods to the enrolled participants according to the allocation sequence. Blinding was applied to all staff involved in this study, including the study coordinator, study operations assistant, data monitoring staff, statistical analysts, test food shipping team, staff at the medical institutions conducting the study, ethics committee members, and staff at third-party clinical testing facilities. The allocation officer sealed and stored the allocation table until the participants and statistical analysis methods were finalized.

Table 1. Composition of test products (per tablet, 1,500 mg).

Product	Shape	Raw material	Net weight
Food containing rosehip extract	Tablet	Rosehip extract	100 mg
		(<i>Trans</i> -tiliroside	0.1 mg)
		Maltitol	893 mg
		Dextrin	150 mg
		Crystalline cellulose	135 mg
		Anhydrous citric acid	40 mg
		Lemon juice powder	50 mg
		Lemon flavoring powder	30 mg
		Other	102 mg
Placebo	Tablet	Rosehip extract	0 mg
		Maltitol	993 mg
		Dextrin	150 mg
		Crystalline cellulose	135 mg
		Anhydrous citric acid	40 mg
		Lemon juice powder	50 mg
		Lemon flavoring powder	30 mg
		Other	102 mg

Intervention: The raw material composition of the test foods used in this study is shown in Table 1. Participants received a test food containing either rosehip-derived tiliroside or a placebo. The rosehip extract powder (Lot 23-CE) manufactured by MJ, an ingredient in the test food, is standardized to contain 0.1% tiliroside. Participants were instructed to chew one tablet orally once daily at a time of their choosing. The intervention period was set to 12 weeks. The test foods were provided in tablet form, and prior to the start of the study, the ethics review confirmed that the two test foods were indistinguishable by color, odor, or taste. Participant adherence to the intervention was monitored by clinical research coordinators at the study site, who checked the participants' daily web-based intake logs throughout the intervention period. Additionally, the investigators sent regular reminders to ensure consistent intake of the test foods throughout the study period.

Data collection and outcomes: Medical Corporation Seishinkai, Takara Clinic (Tokyo, Japan) was responsible for conducting the study. Data were collected in collaboration with Minamimachi Hospital (Tokyo, Japan). Takara Clinic evaluated the collected data and managed the health of the study participants.

The study schedule is shown in Table 2. Efficacy and safety parameters were measured at screening and after 4, 8, and 12 weeks of intervention. We evaluated the following parameters: abdominal fat area (abdominal TFA, abdominal VFA, abdominal subcutaneous fat area [SFA]), body weight, BMI, body fat percentage, fat mass, lean mass, muscle mass, waist circumference, and dietary survey results. Among these parameters, the abdominal VFA

measured after the 12-week intervention was defined as the primary outcome, and the remaining parameters were defined as secondary outcomes.

1) Abdominal fat area in cross-section: Abdominal TFA, VFA, and SFA were measured using computed tomography (CT) images. All clinical and imaging measurements, including the CT scans, were performed at the study site by certified, experienced radiologic technologists and trained clinical research staff. To ensure objectivity and consistency, the CT images for abdominal fat area were analyzed using standardized software (NAEOTOM Alpha; Siemens Healthineers AG, Erlangen, Germany) by experienced analysts blinded to group allocation.

2) Physical measurements and body composition: Body weight, BMI, body fat percentage, fat mass, lean mass, muscle mass, and waist circumference were assessed using a multifrequency body composition analyzer (MC-780A-N; Tanita Corporation, Tokyo, Japan). Participants were instructed to stand barefoot on the electrodes wearing light clothing. All measurements were performed according to the manufacturer's instructions for participant positioning and procedures. Height was measured only at screening and used to calculate BMI. Height was measured to the nearest 0.1 cm using a metal stadiometer (YS-OA; Yoshida Seisakusho Co., Ltd., Tokyo, Japan, or Model HR; Matsuyoshi & Co., Ltd., Tokyo, Japan). To ensure measurement accuracy, participants were instructed to stand barefoot with their heels, buttocks, and upper back touching the vertical metal rod, maintaining the Frankfort horizontal plane.

Table 2. Participant schedule

	Briefing session	Screening examination	Enrolment	Allocation	Start intake	Examination 4 weeks after starting intake	Examination 8 weeks after starting intake	Examination 12 weeks after starting intake
Enrolment			X					
Eligibility screen			X					
Informed consent	X							
Allocation				X				
Intervention:								
Food containing rosehip extract					◆	◆	◆	◆
Placebo					◆	◆	◆	◆
Cross-sectional abdominal fat areas (X-ray computed tomography)		X					X	X
Physical measurements		X				X	X	X
Body composition		X				X	X	X
Dietary survey *		X				X	X	X
Urinalysis		X				X	X	X
Peripheral blood tests		X				X	X	X
Medical interview		X				X	X	X
Diary					◆	◆	◆	◆

X indicates the timing of implementation. ◆ indicates daily measurement or intake.

* Data obtained for the three days prior to each examination date.

3) Dietary survey: A dietary survey was conducted using a calorie and nutrition diary (CAND) [21]. Data were collected over the three days prior to each assessment.

4) Confirmation of adverse events and safety items: Safety assessments included physical measurements, urinalysis, and peripheral blood tests. For the urinalysis and peripheral blood tests, we evaluated the proportion of participants whose values shifted from within the reference range at baseline to outside the reference range postintervention. Additionally, we reviewed the physical measurement, urinalysis, and peripheral blood test data for each group and individual.

Physical measurements included systolic and diastolic blood pressure, which were measured using an Omron HEM-6022 automatic digital blood pressure monitor (OMRON HEALTHCARE Co., Ltd., Kyoto, Japan).

Urinalysis was performed to measure urinary protein, urinary glucose, pH, and occult blood. In addition, peripheral blood tests were conducted to measure white blood cell count, red blood cell count, hemoglobin, hematocrit, platelet count, aspartate aminotransferase, alanine aminotransferase, γ -glutamyl transpeptidase, total bilirubin, total protein, blood urea nitrogen, creatinine, uric acid, sodium, potassium, chloride, serum amylase, total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein cholesterol, triglycerides, glucose, and hemoglobin A1c (NGSP). Each parameter was measured by LSI Medience Corporation (Tokyo, Japan) using standard procedures.

If any symptoms suspected to be adverse events occurred, the principal investigator was required to take the following actions: (1) promptly administer necessary and appropriate treatment; (2) determine whether the trial participant can continue in the study; (3) determine whether it is necessary to activate the emergency code (unblinding); and (4) provide a written assessment of the relationship between the adverse event and the test food.

At each study visit, a medical interview was conducted to confirm the participants' health status. Furthermore, participants were asked to record their daily intake of the test food, any changes in their physical condition, and medication use in a daily diary.

As noted above, the primary outcome of this study was abdominal VFA in apparently healthy adults with an elevated BMI. HOMA-IR was not included as an outcome because participants without overt metabolic disease were expected to have baseline HOMA-IR values largely within the normal range, thereby limiting the ability to detect small intervention-related changes in insulin resistance.

Statistical analysis: Statistical analyses were primarily performed using SPSS version 23.0 for Windows (IBM Japan, Ltd., Tokyo), supplemented by other statistical software as needed. For both efficacy and safety evaluations, missing data were not imputed; all analyses were based on observed cases. Specifically, only data available at each time point were included in the statistical models. All statistical analyses were performed using two-tailed tests, with the significance level set at 5%. This study was based on an analysis focused on the primary outcome, and multiple comparisons for secondary outcomes were not considered. Data analysis methods were executed in accordance with the statistical analysis plan (version 1.0, finalized on August 23, 2024) established prior to unblinding. The statistical analysis plan is available from the corresponding author upon reasonable request and subject to appropriate review.

Baseline characteristics of the study participants are presented as the number of male and female participants per group, and as the mean and standard deviation (SD) for all other variables.

Data for the primary and secondary outcomes are presented as mean and SD. Between-group differences were expressed as the difference between the rosehip and placebo groups (baseline: difference in mean values; postintervention: difference in estimated marginal means [EMMs]). Baseline was defined as the screening value, and between-group comparisons were performed using Welch's t-test. Measured values and changes from baseline in abdominal fat area after the 4-, 8-, and 12-week interventions were compared between groups using a linear mixed model. The baseline value was included as a covariate, with time, group, the time-by-group interaction, the baseline-by-time interaction, study participant, and smoking status as factors. Smoking status was included as

a factor because smoking reportedly affects metabolism and may be associated with increased visceral abdominal fat [22]; its inclusion in the model aimed to improve analytical precision. For the remaining evaluation parameters, measured values and changes from baseline after the 4-, 8-, and 12-week interventions were compared between groups using a linear mixed model, with baseline values as covariates, and time, group, the time-by-group interaction, the baseline-by-time interaction, and study participant as factors. The subgroup analysis conducted in this study used the same analytical methods as the overall analysis.

As part of the safety evaluation, we calculated the adverse event incidence rate for each group, as well as the between-group difference in incidence rates and its 95% CI. We also evaluated the proportion of participants in each group whose urinalysis and peripheral blood test results were within reference ranges at baseline but deviated from these ranges postintervention. Using a chi-square test, we evaluated the between-group differences in these incidence rates and proportions, along with their 95% CIs. Furthermore, the principal investigator reviewed other safety evaluation items at both the individual and group levels, confirming the absence of any clinically significant changes associated with the test food.

RESULTS

Participant flow and analysis set: Of the 180 participants who agreed to participate in the study, 100 were enrolled and randomized by the principal investigator. Of these, 97 participants received their assigned interventions; 3 participants (2 in the rosehip group and 1 in the placebo group) received no intervention after allocation. However, 3 participants (2 in the rosehip group and 1 in the placebo group) did not return to the clinic after the 4-week intervention, 3 participants (1 in the rosehip group and 2 in the placebo group) did not return after the 8-week intervention, and 2 participants (1 in the rosehip group and 1 in the placebo group) did not return after the 12-week intervention (Figure 1).

Based on the ICH E9 definition [23], we prepared two types of full analysis sets (FASs) as the analytical datasets for efficacy evaluation, along with a safety analysis

population (SAF) for safety evaluation. For FAS1, we excluded 3 participants (2 in the rosehip group and 1 in the placebo group) who received no intervention after allocation, and 4 participants (1 in the rosehip group and 3 in the placebo group) without post allocation CT data. Consequently, FAS1 comprised 47 participants in the rosehip group and 46 participants in the placebo group. For FAS2 and the SAF, we excluded 3 participants (2 in the rosehip group and 1 in the placebo group) who received no intervention after allocation. Thus, FAS2 and the SAF retained 48 participants in the rosehip group and 49 participants in the placebo group. Appendix 1 lists the excluded participants for each analysis dataset. The baseline characteristics of the study participants included in the FAS1 and FAS2 are presented in Table 3.1, whereas those of the corresponding subgroup populations (Subgroup 1 and Subgroup 2, defined as participants with a baseline abdominal VFA < 100 cm² within FAS1 and FAS2, respectively) are presented in Table 3.2.

We conducted a subgroup analysis to explore the effects of foods containing rosehip-derived tiliroside on abdominal VFA. Abdominal VFA positively correlates with the number of cardiovascular disease risk factors. Furthermore, when abdominal VFA exceeds 100 cm², the mean number of cardiovascular disease risk factors exceeds 1 in both men and women [8]. Additionally, abdominal visceral fat accumulation induces insulin resistance and leads to pancreatic β -cell dysfunction [24]. According to Japanese guidelines, an abdominal VFA of 100 cm² is the threshold for visceral fat obesity, representing a significantly higher risk for metabolic disorders, regardless of BMI [25]. Based on these findings [8,24,25], among study participants with a BMI ≥ 25 and < 30 kg/m², those with a baseline abdominal VFA < 100 cm² are considered obese but are not suspected of having visceral fat obesity or glucose metabolism abnormalities, and their metabolic functions are expected to differ from those of populations at risk for disease. Therefore, we conducted additional analyses to explore the effects of the rosehip-containing food in this population. The subgroup analysis included 50 participants (24 in the rosehip group and 26 in the placebo group).

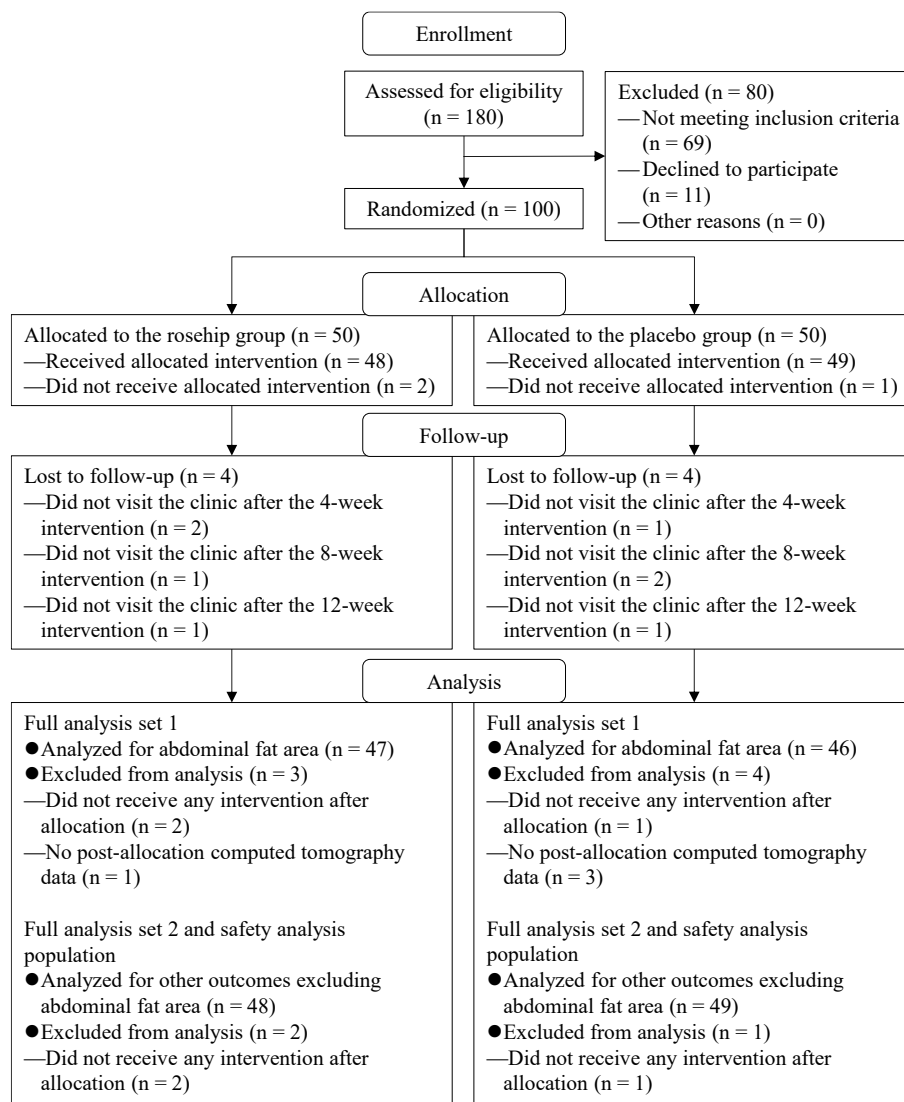


Figure 1. Flowchart of study participants

Table 3.1. Characteristics of study participants (FAS)

Items	Unit	FAS1		FAS2	
		Rosehip group (n = 47)	Placebo group (n = 46)	Rosehip group (n = 48)	Placebo group (n = 49)
Sex	male/female	24/23	24/22	25/23	24/25
Age	year	44.9 (13.1)	44.1 (12.3)	44.5 (13.2)	43.3 (12.6)
Height	cm	163.6 (7.7)	163.9 (7.1)	163.9 (7.9)	163.8 (7.0)
Weight	kg	72.4 (7.9)	72.5 (7.0)	72.5 (7.9)	72.4 (7.0)
BMI	kg/m ²	27.0 (1.3)	26.9 (1.3)	26.9 (1.3)	26.9 (1.3)
Systolic blood pressure	mmHg	120.4 (12.6)	124.0 (17.0)	120.4 (12.5)	122.8 (17.2)
Diastolic blood pressure	mmHg	79.6 (9.9)	81.3 (12.1)	79.4 (9.9)	80.6 (12.2)
Abdominal total fat area	cm ²	336.5 (80.3)	341.7 (73.5)	338.4 (80.6)	337.1 (76.2)
Abdominal visceral fat area	cm ²	102.3 (39.8)	100.7 (38.0)	102.4 (39.4)	100.3 (38.3)
Abdominal subcutaneous fat	cm ²	234.2 (72.8)	241.0 (74.3)	236.1 (73.2)	236.8 (75.3)

Sex is indicated by the number of participants, and other items are indicated by mean and standard deviation. FAS, full analysis set; BMI, body mass index. FAS1 is a dataset for analyzing total, visceral, and subcutaneous abdominal areas that excluded participants with no computed tomography data after the intervention, and FAS2 is a dataset for analyzing other outcomes (excluding abdominal fat areas) that excludes participants with no data after the intervention.

Table 3.2. Characteristics of study participants (Subgroup).

Items	Unit	Subgroup1		Subgroup2	
		Rosehip group (n = 24)	Placebo group (n = 26)	Rosehip group (n = 24)	Placebo group (n = 28)
Sex	male/female	8/16	13/13	8/16	13/15
Age	year	39.8 (12.9)	39.2 (10.7)	39.8 (12.9)	38.1 (11.0)
Height	cm	161.1 (6.9)	163.2 (8.0)	161.1 (6.9)	163.0 (7.9)
Weight	kg	69.7 (6.5)	71.3 (6.7)	69.7 (6.5)	71.2 (6.7)
BMI	kg/m ²	26.8 (1.2)	26.7 (1.1)	26.8 (1.2)	26.7 (1.1)
Systolic blood pressure	mmHg	114.4 (11.2)	121.1 (15.5)	114.4 (11.2)	119.6 (15.9)
Diastolic blood pressure	mmHg	75.8 (9.5)	79.4 (11.9)	75.8 (9.5)	78.3 (12.1)
Abdominal total fat area	cm ²	309.7 (83.8)	330.4 (77.5)	309.7 (83.8)	322.7 (81.6)
Abdominal visceral fat area	cm ²	68.8 (20.3)	72.6 (18.6)	68.8 (20.3)	72.0 (18.2)
Abdominal subcutaneous fat	cm ²	241.0 (76.9)	257.8 (75.3)	241.0 (76.9)	250.7 (79.2)

Sex is indicated by the number of participants, and other items are indicated by mean and standard deviation. FAS, full analysis set; BMI, body mass index. Subgroups 1 and 2 were defined as participants with a baseline abdominal VFA < 100 cm² within FAS1 and FAS2, respectively.

Mean (SD) adherence to the test food regimen in the rosehip and placebo groups was 100.2% (2.2) and 100.5% (2.8) for FAS1; 99.2% (7.4) and 98.5% (10.4) for FAS2 and SAF; 100.1% (2.3) and 101.1% (3.4) for Subgroup1; and 100.1% (2.3) and 99.1% (11.1) for Subgroup 2, respectively. Adherence exceeded the 80% threshold for all participants. A small number of participants were unable to attend their scheduled clinic visits due to personal reasons; therefore, the intervention period was slightly extended for these individuals. Consequently, compliance values exceeded 100% in some cases, which reflects an extended intervention duration rather than increased daily intake.

Abdominal fat areas: In the overall analysis, after the 12-week intervention, the measured abdominal VFA (rosehip group: 90.7 ± 39.6 cm² vs. placebo group: 98.1 ± 35.8 cm²) and the change in abdominal VFA from baseline (rosehip group: -10.6 ± 21.0 cm² vs. placebo group: -1.8 ± 24.9 cm²) indicated a significant reduction in the rosehip group compared with the placebo group (group difference: -9.3

cm² [95% CI: -18.3, -0.3], $P = 0.043$). Both outcomes showed significantly lower values in the rosehip group compared with the placebo group (Table 4).

In the subgroup analysis, after the 12-week intervention, the measured abdominal TFA (rosehip group: 307.9 ± 92.0 cm² vs. placebo group: 347.3 ± 83.1 cm²) and the change in abdominal TFA from baseline (rosehip group: -1.9 ± 35.4 cm² vs. placebo group: 16.9 ± 24.4 cm²) indicated a significant reduction in the rosehip group compared with the placebo group (group difference: -18.9 cm² [95% CI: -36.2, -1.6], $P = 0.033$). Additionally, the measured abdominal VFA (rosehip group: 62.4 ± 26.8 cm² vs. placebo group: 79.1 ± 21.7 cm²) and the change in abdominal VFA from baseline (rosehip group: -6.3 ± 16.4 cm² vs. placebo group: 6.5 ± 16.9 cm²) indicated a significant reduction in the rosehip group compared with the placebo group (group difference: -13.8 cm² [95% CI: -23.1, -4.5], $P = 0.004$). Significant improvements were observed in the rosehip group compared with the placebo group (Table 5).

Table 4. Cross-sectional abdominal fat areas (FAS1)

Items	Unit	Time points	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
Total fat	cm ²	Baseline	Rosehip group	47	336.5	80.3	-	-5.2	0.745
			Placebo group	46	341.7	73.5	-	(-36.9, 26.5)	
		8-week	Rosehip group	47	338.0	90.3	341.2 (330.8, 351.5)	-10.4	0.108
			Placebo group	46	353.3	81.8	351.6 (340.3, 362.8)	(-23.1, 2.3)	
		12-week	Rosehip group	46	333.9	87.9	339.5 (328.8, 350.2)	-12.4	0.068
			Placebo group	45	351.1	80.5	351.9 (340.3, 363.4)	(-25.8, 1.0)	
		Δ8-week	Rosehip group	47	1.5	31.9	3.5 (-6.8, 13.9)	-10.4	0.108
			Placebo group	46	11.6	29.3	13.9 (2.7, 25.2)	(-23.1, 2.3)	
		Δ12-week	Rosehip group	46	0.3	33.0	1.9 (-8.9, 12.6)	-12.4	0.068
			Placebo group	45	12.4	30.8	14.3 (2.7, 25.8)	(-25.8, 1.0)	
Visceral fat	cm ²	Baseline	Rosehip group	47	102.3	39.8	-	1.6	0.847
			Placebo group	46	100.7	38.0	-	(-14.5, 17.6)	
		8-week	Rosehip group	47	99.4	41.3	101.4 (94.3, 108.5)	-1.9	0.669
			Placebo group	46	99.2	36.1	103.3 (95.6, 111.0)	(-10.6, 6.8)	
		12-week	Rosehip group	46	90.7	39.6	93.5 (86.2, 100.7)	-9.3	0.043*
			Placebo group	45	98.1	35.8	102.8 (95.0, 110.6)	(-18.3, -0.3)	
		Δ8-week	Rosehip group	47	-2.9	22.1	0.4 (-6.7, 7.5)	-1.9	0.669
			Placebo group	46	-1.5	22.2	2.3 (-5.4, 9.9)	(-10.6, 6.8)	
		Δ12-week	Rosehip group	46	-10.6	21.0	-7.6 (-14.8, -0.3)	-9.3	0.043*
			Placebo group	45	-1.8	24.9	1.7 (-6.1, 9.5)	(-18.3, -0.3)	
Subcutaneous fat	cm ²	Baseline	Rosehip group	47	234.2	72.8	-	-6.8	0.658
			Placebo group	46	241.0	74.3	-	(-37.1, 23.5)	
		8-week	Rosehip group	47	238.5	79.3	241.5 (230.4, 252.5)	-8.8	0.205
			Placebo group	46	254.1	83.7	250.3 (238.4, 262.2)	(-22.4, 4.9)	
		12-week	Rosehip group	46	243.2	78.0	247.8 (237.1, 258.5)	-3.2	0.625
			Placebo group	45	253.0	83.9	251.0 (239.5, 262.6)	(-16.3, 9.8)	
		Δ8-week	Rosehip group	47	4.3	31.3	4.9 (-6.1, 16.0)	-8.8	0.205
			Placebo group	46	13.1	33.8	13.7 (1.8, 25.6)	(-22.4, 4.9)	
		Δ12-week	Rosehip group	46	10.9	31.1	11.2 (0.6, 21.9)	-3.2	0.625
			Placebo group	45	14.1	31.4	14.5 (2.9, 26.0)	(-16.3, 9.8)	

Data are presented as mean and standard deviation. After the intervention, the estimated marginal mean (EMM) and their 95% confidence interval (CI) are shown. For group differences, the mean difference and its 95% CI are presented at baseline, and the difference in EMM and its 95% CI are shown after the intervention. 4-week, after the 4-week intervention; 8-week, after the 8-week intervention; 12-week, after the 12-week intervention; Δ, change from baseline; *, $P < 0.05$.

Table 5. Cross-sectional abdominal fat areas (Subgroup1).

Items	Unit	Time points	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
Total fat	cm ²	Baseline	Rosehip group	24	309.7	83.8	-	-20.7	0.370
			Placebo group	26	330.4	77.5	-	(-66.8, 25.3)	
		8-week	Rosehip group	24	311.5	94.5	327.8 (311.7, 343.9)	-12.0	0.172
			Placebo group	26	344.1	80.6	339.9 (323.4, 356.3)	(-29.5, 5.4)	
		12-week	Rosehip group	24	307.9	92.0	324.1 (308.1, 340.2)	-18.9	0.033*
			Placebo group	26	347.3	83.1	343.1 (326.7, 359.4)	(-36.2, -1.6)	
		Δ8-week	Rosehip group	24	1.8	34.2	7.4 (-8.7, 23.5)	-12.0	0.172
			Placebo group	26	13.7	25.0	19.4 (2.9, 35.8)	(-29.5, 5.4)	
		Δ12-week	Rosehip group	24	-1.9	35.4	3.7 (-12.4, 19.7)	-18.9	0.033*
			Placebo group	26	16.9	24.4	22.6 (6.2, 39.0)	(-36.2, -1.6)	
Visceral fat	cm ²	Baseline	Rosehip group	24	68.8	20.3	-	-3.9	0.487
			Placebo group	26	72.6	18.6	-	(-15.0, 7.3)	
		8-week	Rosehip group	24	69.0	27.5	75.9 (66.9, 84.8)	-7.0	0.155
			Placebo group	26	79.2	23.2	82.9 (73.7, 92.1)	(-16.8, 2.8)	
		12-week	Rosehip group	24	62.4	26.8	69.2 (60.5, 77.8)	-13.8	0.004*
			Placebo group	26	79.1	21.7	83.0 (74.0, 91.9)	(-23.1, -4.5)	
		Δ8-week	Rosehip group	24	0.2	17.0	5.1 (-3.8, 14.0)	-7.0	0.155
			Placebo group	26	6.6	16.5	12.1 (2.9, 21.3)	(-16.8, 2.7)	
		Δ12-week	Rosehip group	24	-6.3	16.4	-1.6 (-10.3, 7.1)	-13.8	0.004*
			Placebo group	26	6.5	16.9	12.2 (3.2, 21.2)	(-23.1, -4.5)	
Subcutaneous fat	cm ²	Baseline	Rosehip group	24	241.0	76.9	-	-16.8	0.439
			Placebo group	26	257.8	75.3	-	(-60.2, 26.5)	
		8-week	Rosehip group	24	242.5	88.7	253.2 (235.3, 271.1)	-5.2	0.596
			Placebo group	26	265.0	82.3	258.4 (240.2, 276.7)	(-24.8, 14.4)	
		12-week	Rosehip group	24	245.4	87.1	256.4 (239.4, 273.3)	-5.0	0.573
			Placebo group	26	268.2	85.9	261.4 (244.0, 278.8)	(-22.9, 12.8)	
		Δ8-week	Rosehip group	24	1.6	36.7	3.5 (-14.4, 21.4)	-5.2	0.596
			Placebo group	26	7.2	30.3	8.7 (-9.5, 27.0)	(-24.8, 14.4)	
		Δ12-week	Rosehip group	24	4.5	34.6	6.7 (-10.3, 23.6)	-5.0	0.573
			Placebo group	26	10.4	26.8	11.7 (-5.7, 29.1)	(-22.9, 12.8)	

Data are presented as mean and standard deviation. After the intervention, the estimated marginal mean (EMM) and their 95% confidence interval (CI) are shown. For group differences, the mean difference and its 95% CI are presented at baseline, and the difference in EMM and its 95% CI are shown after the intervention. 4-week, after the 4-week intervention; 8-week, after the 8-week intervention; 12-week, after the 12-week intervention; Δ, change from baseline; *, $P < 0.05$.

Physical measurements and body composition: In the overall analysis, after the 4-week intervention, the measured body fat percentage (rosehip group $32.1 \pm 8.3\%$ vs. placebo group $33.8 \pm 7.8\%$) and the change in body fat percentage from baseline (rosehip group $-0.6 \pm 2.4\%$ vs. placebo group $0.4 \pm 1.6\%$), the fat mass (rosehip group: 23.1 ± 5.8 kg vs. placebo group: 24.4 ± 5.5 kg), and the change in fat mass (rosehip group: -0.4 ± 2.1 kg vs. placebo group: 0.4 ± 1.5 kg) were significantly different between the groups (body fat percentage, group difference: -1.1% [95% CI: $-1.9, -0.2$], $P = 0.013$ / fat mass, group difference: -0.8 kg [95% CI: $-1.5, 0.0$], $P = 0.040$). These outcomes were lower in the rosehip group than in the placebo group (Table 6).

Conversely, significant differences between the groups after the 4-week intervention were observed in the following outcomes: the measured lean mass (rosehip group: 49.5 ± 9.2 kg vs. placebo group: 48.2 ± 8.4 kg), the change in lean mass (rosehip group: 0.5 ± 1.8 kg vs. placebo group: -0.2 ± 1.2 kg), the measured muscle mass (rosehip group 46.8 ± 8.9 kg vs. placebo group 45.6 ± 8.1 kg), and the change in muscle mass (rosehip group 0.5 ± 1.7 kg vs. placebo group -0.2 ± 1.1 kg). These results were higher in the rosehip group than in the placebo group (lean mass, group difference: 0.7 kg [95% CI: $0.1, 1.3$], $P = 0.020$ / muscle mass, group difference: 0.7 kg [95% CI: $0.1, 1.2$], $P = 0.021$, Table 6).

In the subgroup analysis, no significant differences were observed (Table 7).

Dietary survey: In the overall analysis, following the 12-week intervention, significant differences between the

groups were observed in measured energy intake (rosehip group: 2258.2 ± 702.6 kcal vs. placebo group: 2496.4 ± 1089.2 kcal) and the change in energy intake from baseline (rosehip group: -172.3 ± 770.3 kcal vs. placebo group: 203.3 ± 780.7 kcal), as well as in measured protein intake (rosehip group: 88.2 ± 26.2 g vs. placebo group: 100.3 ± 49.0 g) and the change in protein intake from baseline (rosehip group: -9.7 ± 32.5 g vs. placebo group: 7.9 ± 39.5 g). Both outcomes were lower in the rosehip group than in the placebo group (energy, group difference: -308.3 kcal [95% CI: $-612.0, -4.7$], $P = 0.047$ / protein, group difference: -15.2 g [95% CI: $-29.1, -1.4$], $P = 0.032$, Table 8).

In the subgroup analysis, no significant differences were observed (Table 9).

Confirmation of adverse events and safety items: No adverse events were observed in this study (data not shown). Additionally, significant between-group differences were observed in the proportion of participants whose values shifted from the normal range at baseline to outside the normal range after the intervention. This included the results for total bilirubin (after the 4- and 8-week interventions), total cholesterol (after the 8-week intervention), and blood urea nitrogen, creatinine, and serum amylase (after the 12-week intervention; Appendix 2). The principal investigator reviewed the physical measurements, urinalysis, and peripheral blood test data for the safety assessment parameters at the group level (Appendices 3–5) and individual level (data not shown), and no clinically significant changes were identified.

Table 6. Physical measurements and body composition (FAS2).

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
Weight	kg	Baseline	Rosehip group	48	72.5	7.9	-	0.1 (−2.9, 3.1)	0.923
			Placebo group	49	72.4	7.0	-		
		4-week	Rosehip group	48	72.7	7.9	72.6 (72.1, 73.1)	−0.1 (−0.8, 0.6)	0.787
			Placebo group	49	72.6	7.0	72.7 (72.2, 73.2)		
		8-week	Rosehip group	47	72.4	8.0	72.5 (71.9, 73.1)	−0.1 (−0.9, 0.7)	0.809
			Placebo group	47	72.7	7.1	72.6 (72.0, 73.1)		
		12-week	Rosehip group	46	72.2	8.2	72.2 (71.6, 72.9)	−0.3 (−1.2, 0.6)	0.525
			Placebo group	46	72.6	7.5	72.6 (71.9, 73.2)		
		Δ4-week	Rosehip group	48	0.2	1.7	0.2 (−0.3, 0.6)	−0.1 (−0.8, 0.6)	0.787
			Placebo group	49	0.3	1.6	0.2 (−0.2, 0.7)		
		Δ8-week	Rosehip group	47	0.1	2.1	0.0 (−0.5, 0.6)	−0.1 (−0.9, 0.7)	0.809
			Placebo group	47	0.1	1.8	0.1 (−0.4, 0.7)		
		Δ12-week	Rosehip group	46	−0.2	2.5	−0.2 (−0.9, 0.4)	−0.3 (−1.2, 0.6)	0.525
			Placebo group	46	0.0	2.0	0.1 (−0.6, 0.7)		
BMI	kg/m ²	Baseline	Rosehip group	48	26.9	1.3	-	0.0 (−0.5, 0.5)	0.977
			Placebo group	49	26.9	1.3	-		
		4-week	Rosehip group	48	27.0	1.5	27.0 (26.8, 27.2)	0.0 (−0.3, 0.2)	0.789
			Placebo group	49	27.0	1.5	27.0 (26.9, 27.2)		
		8-week	Rosehip group	47	27.0	1.5	27.0 (26.8, 27.2)	0.0 (−0.3, 0.3)	0.824
			Placebo group	47	27.0	1.5	27.0 (26.8, 27.2)		
		12-week	Rosehip group	46	26.9	1.7	26.9 (26.6, 27.1)	−0.1 (−0.4, 0.3)	0.599
			Placebo group	46	26.9	1.6	27.0 (26.7, 27.2)		
		Δ4-week	Rosehip group	48	0.1	0.7	0.1 (−0.1, 0.3)	0.0 (−0.3, 0.2)	0.789
			Placebo group	49	0.1	0.6	0.1 (−0.1, 0.3)		
		Δ8-week	Rosehip group	47	0.0	0.8	0.0 (−0.2, 0.2)	0.0 (−0.3, 0.3)	0.824
			Placebo group	47	0.0	0.7	0.1 (−0.1, 0.3)		
		Δ12-week	Rosehip group	46	−0.1	1.0	−0.1 (−0.3, 0.2)	−0.1 (−0.4, 0.3)	0.599
			Placebo group	46	0.0	0.8	0.0 (−0.2, 0.3)		
Body fat percentage	%	Baseline	Rosehip group	48	32.7	7.6	-	−0.6 (−3.7, 2.5)	0.691
			Placebo group	49	33.4	7.8	-		
		4-week	Rosehip group	48	32.1	8.3	32.3 (31.7, 32.9)	−1.1 (−1.9, −0.2)	0.013*
			Placebo group	49	33.8	7.8	33.4 (32.8, 34.0)		
		8-week	Rosehip group	47	33.0	7.5	32.9 (32.4, 33.4)	−0.4 (−1.1, 0.4)	0.321

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
			Placebo group	47	33.3	8.0	33.3 (32.8, 33.8)		
		12-week	Rosehip group	46	32.1	8.0	32.3 (31.7, 32.8)	−0.6 (−1.3, 0.2)	0.140
			Placebo group	46	32.6	8.0	32.8 (32.3, 33.4)		
		Δ4-week	Rosehip group	48	−0.6	2.4	−0.6 (−1.2, 0.0)	−1.1 (−1.9, −0.2)	0.013*
			Placebo group	49	0.4	1.6	0.4 (−0.2, 1.0)		
		Δ8-week	Rosehip group	47	0.0	1.8	0.0 (−0.6, 0.5)	−0.4 (−1.1, 0.4)	0.321
			Placebo group	47	0.3	1.8	0.3 (−0.2, 0.9)		
		Δ12-week	Rosehip group	46	−0.7	2.0	−0.7 (−1.2, −0.1)	−0.6 (−1.3, 0.2)	0.140
			Placebo group	46	−0.1	1.8	−0.1 (−0.6, 0.4)		
Fat mass	kg	Baseline	Rosehip group	48	23.5	4.9	-	−0.5 (−2.5, 1.6)	0.654
			Placebo group	49	24.0	5.4	-		
		4-week	Rosehip group	48	23.1	5.8	23.3 (22.8, 23.8)	−0.8 (−1.5, 0.0)	0.040*
			Placebo group	49	24.4	5.5	24.1 (23.6, 24.6)		
		8-week	Rosehip group	47	23.7	5.2	23.7 (23.2, 24.2)	−0.3 (−1.0, 0.4)	0.436
			Placebo group	47	24.0	5.7	24.0 (23.5, 24.5)		
		12-week	Rosehip group	46	23.0	5.7	23.2 (22.6, 23.7)	−0.5 (−1.3, 0.3)	0.225
			Placebo group	46	23.5	5.8	23.7 (23.1, 24.2)		
		Δ4-week	Rosehip group	48	−0.4	2.1	−0.4 (−0.9, 0.2)	−0.8 (−1.5, 0.0)	0.040*
			Placebo group	49	0.4	1.5	0.4 (−0.1, 0.9)		
		Δ8-week	Rosehip group	47	0.0	1.8	0.0 (−0.5, 0.5)	−0.3 (−1.0, 0.4)	0.436
			Placebo group	47	0.3	1.7	0.3 (−0.2, 0.8)		
		Δ12-week	Rosehip group	46	−0.5	2.1	−0.5 (−1.1, 0.1)	−0.5 (−1.3, 0.3)	0.225
			Placebo group	46	0.0	1.8	0.0 (−0.6, 0.6)		
Lean mass	kg	Baseline	Rosehip group	48	49.0	9.1	-	0.6 (−3.0, 4.2)	0.733
			Placebo group	49	48.4	8.6	-		
		4-week	Rosehip group	48	49.5	9.2	49.3 (48.9, 49.8)	0.7 (0.1, 1.3)	0.020*
			Placebo group	49	48.2	8.4	48.6 (48.2, 49.0)		
		8-week	Rosehip group	47	48.8	8.9	48.8 (48.5, 49.1)	0.2 (−0.2, 0.7)	0.295
			Placebo group	47	48.6	8.5	48.6 (48.3, 48.9)		
		12-week	Rosehip group	46	49.2	9.1	49.1 (48.8, 49.4)	0.2 (−0.2, 0.7)	0.319
			Placebo group	46	49.1	8.7	48.9 (48.5, 49.2)		
		Δ4-week	Rosehip group	48	0.5	1.8	0.5 (0.1, 0.9)	0.7 (0.1, 1.3)	0.020*
			Placebo group	49	−0.2	1.2	−0.2 (−0.6, 0.2)		
		Δ8-week	Rosehip group	47	0.0	1.0	0.0 (−0.3, 0.3)	0.2 (−0.2, 0.7)	0.295

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
Muscle mass	kg	Baseline	Placebo group	47	-0.2	1.1	-0.2 (-0.5, 0.1)	0.2 (-0.2, 0.7)	0.319
			Rosehip group	46	0.3	1.2	0.3 (0.0, 0.6)		
		4-week	Placebo group	46	0.0	1.1	0.1 (-0.3, 0.4)	0.6 (-2.8, 4.0)	0.729
			Rosehip group	48	46.3	8.8	-		
		8-week	Placebo group	49	45.7	8.3	-	0.7 (0.1, 1.2)	0.021*
			Rosehip group	48	46.8	8.9	46.6 (46.2, 47.0)		
		12-week	Placebo group	49	45.6	8.1	46.0 (45.6, 46.4)	0.2 (-0.2, 0.6)	0.297
			Rosehip group	47	46.1	8.5	46.2 (45.9, 46.4)		
		Δ4-week	Placebo group	47	46.0	8.1	45.9 (45.6, 46.2)	0.2 (-0.2, 0.7)	0.314
			Rosehip group	46	46.5	8.7	46.4 (46.1, 46.7)		
		Δ8-week	Placebo group	46	46.4	8.3	46.2 (45.9, 46.5)	0.7 (0.1, 1.2)	0.021*
			Rosehip group	48	0.5	1.7	0.5 (0.1, 0.9)		
Waist circumference	cm	Baseline	Placebo group	49	-0.2	1.1	-0.2 (-0.6, 0.2)	0.2 (-0.2, 0.6)	0.297
			Rosehip group	47	0.0	1.0	0.0 (-0.3, 0.3)		
		4-week	Placebo group	47	-0.2	1.1	-0.2 (-0.5, 0.1)	0.2 (-0.2, 0.7)	0.314
			Rosehip group	46	0.3	1.2	0.3 (0.0, 0.6)		
		8-week	Placebo group	46	0.0	1.1	0.0 (-0.3, 0.4)	-1.0 (-3.7, 1.7)	0.458
			Rosehip group	48	93.6	6.8	-		
		12-week	Placebo group	49	94.6	6.3	-	0.3 (-1.2, 1.7)	0.712
			Rosehip group	48	93.3	7.2	93.8 (92.8, 94.8)		
		Δ4-week	Placebo group	49	93.9	5.6	93.5 (92.5, 94.5)	-0.5 (-1.9, 1.0)	0.499
			Rosehip group	47	93.0	7.4	93.4 (92.3, 94.4)		
		Δ8-week	Placebo group	47	94.5	6.4	93.9 (92.8, 94.9)	-0.4 (-1.9, 1.1)	0.565
			Rosehip group	46	93.2	7.7	93.8 (92.7, 94.8)		
		Baseline	Placebo group	46	94.7	6.9	94.2 (93.1, 95.2)	0.3 (-1.2, 1.7)	0.712
			Rosehip group	48	-0.2	3.5	-0.3 (-1.3, 0.7)		
		4-week	Placebo group	49	-0.7	3.9	-0.6 (-1.6, 0.4)	-0.5 (-1.9, 1.0)	0.499
			Rosehip group	47	-0.6	3.9	-0.7 (-1.8, 0.3)		
		8-week	Placebo group	47	-0.3	3.2	-0.2 (-1.3, 0.8)	-0.4 (-1.9, 1.1)	0.565
			Rosehip group	46	-0.3	3.8	-0.4 (-1.4, 0.7)		
		Δ12-week	Placebo group	46	0.1	3.5	0.1 (-1.0, 1.1)		

Data are presented as mean and standard deviation. After the intervention, the estimated marginal mean (EMM) and its 95% confidence interval (CI) are shown. For group differences, the mean difference and its 95% CI are presented at baseline, and the EMM difference and its 95% CI are shown after the intervention. 4-week, after the 4-week intervention; 8-week, after the 8-week intervention; 12-week, after the 12-week intervention; Δ, change from baseline; BMI, body mass index; *, $P < 0.05$.

Table 7. Physical measurements and body composition (Subgroup2).

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
Weight	kg	Baseline	Rosehip group	24	69.7	6.5	-	-1.5 (-5.2, 2.2)	0.429
			Placebo group	28	71.2	6.7	-		
		4-week	Rosehip group	24	69.9	6.9	70.8 (70.0, 71.5)	-0.5 (-1.5, 0.6)	0.376
			Placebo group	28	71.8	7.1	71.2 (70.5, 71.9)		
		8-week	Rosehip group	24	69.6	7.2	70.5 (69.7, 71.4)	-0.6 (-1.8, 0.5)	0.279
			Placebo group	27	72.1	7.1	71.1 (70.4, 71.9)		
		12-week	Rosehip group	24	69.3	7.3	70.3 (69.3, 71.3)	-0.7 (-2.0, 0.7)	0.307
			Placebo group	27	71.9	7.5	71.0 (70.1, 71.9)		
		Δ4-week	Rosehip group	24	0.2	2.0	0.2 (-0.6, 0.9)	-0.5 (-1.5, 0.6)	0.376
			Placebo group	28	0.7	1.7	0.6 (-0.1, 1.4)		
		Δ8-week	Rosehip group	24	-0.1	2.4	-0.1 (-0.9, 0.8)	-0.6 (-1.8, 0.5)	0.279
			Placebo group	27	0.6	1.7	0.6 (-0.2, 1.3)		
		Δ12-week	Rosehip group	24	-0.3	2.8	-0.3 (-1.3, 0.7)	-0.7 (-2.0, 0.7)	0.307
			Placebo group	27	0.4	2.0	0.4 (-0.5, 1.3)		
BMI	kg/m ²	Baseline	Rosehip group	24	26.8	1.2	-	0.1 (-0.6, 0.7)	0.783
			Placebo group	28	26.7	1.1	-		
		4-week	Rosehip group	24	26.9	1.5	26.8 (26.6, 27.1)	-0.2 (-0.6, 0.2)	0.331
			Placebo group	28	27.0	1.3	27.0 (26.8, 27.3)		
		8-week	Rosehip group	24	26.8	1.5	26.8 (26.4, 27.1)	-0.3 (-0.7, 0.2)	0.241
			Placebo group	27	27.0	1.4	27.0 (26.7, 27.3)		
		12-week	Rosehip group	24	26.7	1.7	26.7 (26.3, 27.0)	-0.3 (-0.8, 0.2)	0.240
			Placebo group	27	26.9	1.6	27.0 (26.6, 27.3)		
		Δ4-week	Rosehip group	24	0.1	0.8	0.1 (-0.2, 0.4)	-0.2 (-0.6, 0.2)	0.331
			Placebo group	28	0.3	0.6	0.3 (0.0, 0.5)		
		Δ8-week	Rosehip group	24	0.0	0.9	0.0 (-0.3, 0.3)	-0.3 (-0.7, 0.2)	0.241
			Placebo group	27	0.2	0.7	0.2 (-0.1, 0.5)		
		Δ12-week	Rosehip group	24	-0.1	1.1	-0.1 (-0.5, 0.2)	-0.3 (-0.8, 0.2)	0.240
			Placebo group	27	0.2	0.7	0.2 (-0.1, 0.5)		

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
			Placebo group	27	0.2	0.8	0.2 (−0.2, 0.5)		
Body fat percentage	%	Baseline	Rosehip group	24	34.9	8.2	-	1.5 (−3.0, 6.0)	0.517
			Placebo group	28	33.4	7.8	-		
		4-week	Rosehip group	24	34.5	8.2	33.7 (32.9, 34.5)	−0.9 (−2.0, 0.2)	0.099
			Placebo group	28	34.0	7.6	34.6 (33.8, 35.3)		
		8-week	Rosehip group	24	34.6	8.1	33.8 (32.9, 34.7)	−0.7 (−1.9, 0.5)	0.247
			Placebo group	27	33.6	7.9	34.5 (33.7, 35.3)		
		12-week	Rosehip group	24	34.1	8.6	33.2 (32.3, 34.1)	−0.9 (−2.1, 0.3)	0.144
			Placebo group	27	33.2	8.3	34.1 (33.3, 34.9)		
		Δ4-week	Rosehip group	24	−0.3	1.7	−0.3 (−1.1, 0.5)	−0.9 (−2.0, 0.2)	0.099
			Placebo group	28	0.6	2.0	0.6 (−0.1, 1.3)		
		Δ8-week	Rosehip group	24	−0.2	2.2	−0.2 (−1.1, 0.7)	−0.7 (−1.9, 0.5)	0.247
			Placebo group	27	0.5	2.1	0.5 (−0.3, 1.3)		
		Δ12-week	Rosehip group	24	−0.8	2.2	−0.8 (−1.7, 0.1)	−0.9 (−2.1, 0.3)	0.144
			Placebo group	27	0.1	2.2	0.1 (−0.7, 1.0)		
Fat mass	kg	Baseline	Rosehip group	24	24.2	5.8	-	0.6 (−2.5, 3.7)	0.697
			Placebo group	28	23.6	5.2	-		
		4-week	Rosehip group	24	24.1	6.3	23.7 (23.0, 24.5)	−0.8 (−1.8, 0.2)	0.129
			Placebo group	28	24.3	5.3	24.5 (23.8, 25.2)		
		8-week	Rosehip group	24	24.0	6.1	23.7 (22.8, 24.5)	−0.8 (−1.9, 0.4)	0.182
			Placebo group	27	24.1	5.7	24.4 (23.7, 25.2)		
		12-week	Rosehip group	24	23.6	6.5	23.2 (22.3, 24.1)	−1.0 (−2.2, 0.3)	0.121
			Placebo group	27	23.8	6.1	24.1 (23.3, 25.0)		
		Δ4-week	Rosehip group	24	−0.1	1.9	−0.1 (−0.9, 0.7)	−0.8 (−1.8, 0.2)	0.129
			Placebo group	28	0.7	1.8	0.7 (0.0, 1.4)		
		Δ8-week	Rosehip group	24	−0.1	2.2	−0.1 (−1.0, 0.7)	−0.8 (−1.9, 0.4)	0.182
			Placebo group	27	0.6	1.9	0.6 (−0.2, 1.4)		
		Δ12-week	Rosehip group	24	−0.6	2.4	−0.6 (−1.5, 0.3)	−1.0 (−2.2, 0.3)	0.121

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
			Placebo group	27	0.3	2.0	0.3 (−0.5, 1.2)		
Lean mass	kg	Baseline	Rosehip group	24	45.5	8.2	-	−2.1 (−6.8, 2.6)	0.379
			Placebo group	28	47.6	8.6	-		
		4-week	Rosehip group	24	45.8	7.8	47.0 (46.5, 47.5)	0.2 (−0.5, 0.9)	0.528
			Placebo group	28	47.6	8.4	46.8 (46.3, 47.2)		
		8-week	Rosehip group	24	45.6	8.0	46.8 (46.3, 47.3)	0.0 (−0.6, 0.7)	0.911
			Placebo group	27	48.0	8.4	46.8 (46.3, 47.2)		
		12-week	Rosehip group	24	45.8	8.2	47.0 (46.5, 47.5)	0.1 (−0.5, 0.8)	0.701
			Placebo group	27	48.2	8.7	46.9 (46.5, 47.4)		
		Δ4-week	Rosehip group	24	0.3	1.1	0.2 (−0.3, 0.7)	0.2 (−0.5, 0.9)	0.528
			Placebo group	28	0.0	1.4	0.0 (−0.5, 0.4)		
		Δ8-week	Rosehip group	24	0.0	1.1	0.0 (−0.5, 0.5)	0.0 (−0.6, 0.7)	0.911
			Placebo group	27	0.0	1.2	0.0 (−0.5, 0.4)		
		Δ12-week	Rosehip group	24	0.3	1.1	0.3 (−0.2, 0.8)	0.1 (−0.5, 0.8)	0.701
			Placebo group	27	0.2	1.2	0.1 (−0.3, 0.6)		
Muscle mass	kg	Baseline	Rosehip group	24	43.0	7.8	-	−2.0 (−6.5, 2.5)	0.379
			Placebo group	28	45.0	8.3	-		
		4-week	Rosehip group	24	43.2	7.5	44.4 (43.9, 44.8)	0.2 (−0.5, 0.8)	0.559
			Placebo group	28	44.9	8.1	44.2 (43.7, 44.6)		
		8-week	Rosehip group	24	43.0	7.7	44.2 (43.7, 44.6)	0.0 (−0.6, 0.7)	0.929
			Placebo group	27	45.3	8.1	44.2 (43.7, 44.6)		
		12-week	Rosehip group	24	43.2	7.9	44.4 (44.0, 44.9)	0.1 (−0.5, 0.7)	0.704
			Placebo group	27	45.5	8.4	44.3 (43.9, 44.7)		
		Δ4-week	Rosehip group	24	0.2	1.0	0.2 (−0.3, 0.7)	0.2 (−0.5, 0.8)	0.559
			Placebo group	28	0.0	1.3	0.0 (−0.4, 0.4)		
		Δ8-week	Rosehip group	24	0.0	1.0	0.0 (−0.4, 0.5)	0.0 (−0.6, 0.7)	0.929
			Placebo group	27	0.0	1.2	0.0 (−0.4, 0.4)		
		Δ12-week	Rosehip group	24	0.2	1.0	0.2 (−0.2, 0.7)	0.1 (−0.5, 0.7)	0.704

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
			Placebo group	27	0.1	1.2	0.1 (−0.3, 0.5)		
Waist circumference	cm	Baseline	Rosehip group	24	90.3	7.0	-	−3.2 (−7.1, 0.6)	0.098
			Placebo group	28	93.5	6.7	-		
		4-week	Rosehip group	24	90.2	7.2	91.7 (90.3, 93.1)	−0.3 (−2.2, 1.6)	0.746
			Placebo group	28	93.1	5.6	92.0 (90.7, 93.3)		
		8-week	Rosehip group	24	89.3	7.0	90.9 (89.6, 92.3)	−1.3 (−3.3, 0.6)	0.169
			Placebo group	27	93.8	6.7	92.3 (91.0, 93.6)		
		12-week	Rosehip group	24	89.4	7.4	91.1 (89.7, 92.5)	−1.2 (−3.2, 0.7)	0.202
			Placebo group	27	94.0	7.3	92.4 (91.1, 93.6)		
		Δ4-week	Rosehip group	24	0.0	2.7	−0.4 (−1.8, 1.0)	−0.3 (−2.2, 1.6)	0.746
			Placebo group	28	−0.4	4.1	−0.1 (−1.4, 1.2)		
		Δ8-week	Rosehip group	24	−0.9	3.5	−1.1 (−2.5, 0.2)	−1.3 (−3.3, 0.6)	0.169
			Placebo group	27	0.0	3.3	0.2 (−1.1, 1.5)		
		Δ12-week	Rosehip group	24	−0.9	3.2	−1.0 (−2.3, 0.4)	−1.2 (−3.2, 0.7)	0.202
			Placebo group	27	0.2	3.3	0.3 (−1.0, 1.6)		

Data are presented as mean and standard deviation (SD). After the intervention, estimated marginal mean (EMM) and its 95% confidence interval (CI) are shown. For group differences, the mean difference and its 95% CI are presented at baseline, and the EMM difference and its 95% CI are shown after the intervention. 4-week, after the 4-week intervention; 8-week, after the 8-week intervention; 12-week, after the 12-week intervention; Δ, change from baseline; BMI, body mass index.

Table 8. Dietary survey results (FAS2).

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
Energy	kcal	Baseline	Rosehip group	48	2401.0	883.8	-	81.5 (−247.0, 410.0)	0.623
			Placebo group	49	2319.5	736.8	-		
		4-week	Rosehip group	48	2250.5	646.3	2227.5 (2056.0, 2398.9)	−212.6 (−454.0, 28.8)	0.084
			Placebo group	49	2417.8	833.6	2440.1 (2270.4, 2609.8)		
		8-week	Rosehip group	47	2359.1	708.0	2336.7 (2187.7, 2485.8)	−89.5 (−300.3, 121.2)	0.401
			Placebo group	47	2401.4	631.7	2426.3 (2277.6, 2575.0)		
		12-week	Rosehip group	46	2258.2	702.6	2231.3 (2016.6, 2446.0)	−308.3 (−612.0, −4.7)	0.047*
			Placebo group	46	2496.4	1089.2	2539.7 (2325.6, 2753.8)		
		Δ4-week	Rosehip group	48	−150.5	798.8	−132.1 (−303.6, 39.4)	−212.6 (−454.0, 28.8)	0.084

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
			Placebo group	49	98.3	577.4	80.5 (−89.2, 250.2)		
		Δ8-week	Rosehip group	47	−55.0	704.8	−22.8 (−171.8, 126.2)	−89.5 (−300.3, 121.2)	0.401
			Placebo group	47	101.3	550.5	66.7 (−82.0, 215.4)		
		Δ12-week	Rosehip group	46	−172.3	770.3	−128.3 (−343.0, 86.5)	−308.3 (−612.0, −4.7)	0.047*
			Placebo group	46	203.3	780.7	180.1 (−34.0, 394.2)		
Protein	g	Baseline	Rosehip group	48	96.9	37.3	-	3.9 (−9.7, 17.5)	0.572
			Placebo group	49	93.0	29.6	-		
		4-week	Rosehip group	48	91.8	29.0	90.8 (82.8, 98.8)	−8.1 (−19.4, 3.2)	0.156
			Placebo group	49	97.9	36.4	98.9 (91.0, 106.9)		
		8-week	Rosehip group	47	94.5	27.8	93.3 (86.5, 100.2)	−4.9 (−14.6, 4.8)	0.321
			Placebo group	47	97.3	29.1	98.2 (91.4, 105.1)		
		12-week	Rosehip group	46	88.2	26.2	86.8 (77.0, 96.6)	−15.2 (−29.1, −1.4)	0.032*
			Placebo group	46	100.3	49.0	102.0 (92.2, 111.8)		
		Δ4-week	Rosehip group	48	−5.1	35.6	−4.2 (−12.2, 3.8)	−8.1 (−19.4, 3.2)	0.156
			Placebo group	49	4.9	28.0	3.9 (−4.0, 11.8)		
		Δ8-week	Rosehip group	47	−2.9	31.6	−1.7 (−8.5, 5.2)	−4.9 (−14.6, 4.8)	0.321
			Placebo group	47	4.6	27.2	3.2 (−3.6, 10.1)		
		Δ12-week	Rosehip group	46	−9.7	32.5	−8.2 (−18.1, 1.6)	−15.2 (−29.1, −1.4)	0.032*
			Placebo group	46	7.9	39.5	7.0 (−2.8, 16.8)		
Lipid	g	Baseline	Rosehip group	48	83.1	35.8	-	3.0 (−10.3, 16.3)	0.656
			Placebo group	49	80.1	29.8	-		
		4-week	Rosehip group	48	78.8	31.6	78.0 (69.8, 86.1)	−8.4 (−19.9, 3.0)	0.147
			Placebo group	49	85.5	35.6	86.4 (78.3, 94.4)		
		8-week	Rosehip group	47	84.1	29.1	83.0 (76.5, 89.6)	−2.6 (−11.9, 6.7)	0.579
			Placebo group	47	85.1	28.1	85.6 (79.1, 92.2)		
		12-week	Rosehip group	46	78.4	29.0	77.5 (68.1, 86.8)	−11.8 (−25.0, 1.4)	0.080
			Placebo group	46	87.9	44.3	89.3 (80.0, 98.6)		
		Δ4-week	Rosehip group	48	−4.3	34.3	−3.6 (−11.8, 4.5)	−8.4 (−19.9, 3.0)	0.147
			Placebo group	49	5.4	28.9	4.8 (−3.3, 12.8)		
		Δ8-week	Rosehip group	47	0.5	30.0	1.4 (−5.1, 8.0)	−2.6 (−11.9, 6.7)	0.579
			Placebo group	47	5.5	23.8	4.0 (−2.5, 10.6)		
		Δ12-week	Rosehip group	46	−5.5	29.0	−4.1 (−13.5, 5.2)	−11.8 (−25.0, 1.4)	0.080

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
			Placebo group	46	8.5	38.9	7.7 (–1.7, 17.0)		
Carbohydrate	g	Baseline	Rosehip group	48	294.2	109.4	-	9.1 (–31.8, 50.0)	0.659
			Placebo group	49	285.0	92.6	-		
		4-week	Rosehip group	48	273.1	83.6	270.1 (249.1, 291.2)	–25.3 (–54.9, 4.4)	0.094
			Placebo group	49	293.0	104.1	295.4 (274.6, 316.3)		
		8-week	Rosehip group	47	287.5	90.6	285.8 (265.8, 305.8)	–5.9 (–34.2, 22.4)	0.680
			Placebo group	47	288.1	81.2	291.7 (271.7, 311.7)		
		12-week	Rosehip group	46	281.4	101.2	277.4 (252.0, 302.9)	–30.8 (–66.8, 5.3)	0.093
			Placebo group	46	301.8	127.6	308.2 (282.8, 333.7)		
		Δ4-week	Rosehip group	48	–21.0	100.1	–19.0 (–40.0, 2.1)	–25.3 (–54.9, 4.4)	0.094
			Placebo group	49	8.0	64.5	6.3 (–14.5, 27.2)		
		Δ8-week	Rosehip group	47	–8.0	89.9	–3.3 (–23.3, 16.7)	–5.9 (–34.2, 22.4)	0.680
			Placebo group	47	6.5	77.3	2.6 (–17.4, 22.5)		
		Δ12-week	Rosehip group	46	–16.5	101.5	–11.7 (–37.1, 13.8)	–30.8 (–66.8, 5.3)	0.093
			Placebo group	46	21.4	76.9	19.1 (–6.3, 44.5)		
Dietary fiber	g	Baseline	Rosehip group	48	15.5	5.8	-	1.0 (–1.3, 3.3)	0.386
			Placebo group	49	14.5	5.5	-		
		4-week	Rosehip group	48	14.3	4.5	14.0 (12.7, 15.3)	–1.7 (–3.5, 0.1)	0.063
			Placebo group	49	15.5	6.2	15.7 (14.5, 17.0)		
		8-week	Rosehip group	47	15.5	6.3	15.1 (13.7, 16.5)	–0.3 (–2.3, 1.7)	0.765
			Placebo group	47	15.2	5.5	15.4 (14.0, 16.8)		
		12-week	Rosehip group	46	14.4	5.7	14.0 (12.4, 15.7)	–2.0 (–4.4, 0.4)	0.095
			Placebo group	46	15.5	8.1	16.0 (14.4, 17.7)		
		Δ4-week	Rosehip group	48	–1.2	5.6	–0.9 (–2.2, 0.3)	–1.7 (–3.5, 0.1)	0.063
			Placebo group	49	1.0	4.7	0.8 (–0.5, 2.0)		
		Δ8-week	Rosehip group	47	0.0	5.7	0.2 (–1.2, 1.6)	–0.3 (–2.3, 1.7)	0.765
			Placebo group	47	0.8	4.9	0.5 (–0.9, 1.9)		
		Δ12-week	Rosehip group	46	–1.1	5.6	–0.9 (–2.6, 0.8)	–2.0 (–4.4, 0.4)	0.095
			Placebo group	46	1.2	6.1	1.1 (–0.6, 2.8)		

Data are presented as mean and standard deviation. After the intervention, the estimated marginal mean (EMM) and their 95% confidence interval (CI) are shown. For group differences, the mean difference and its 95% CI are presented at baseline, and the difference in EMM and its 95% CI are shown after the intervention. 4-week, after the 4-week intervention; 8-week, after the 8-week intervention; 12-week, after the 12-week intervention; Δ, change from baseline; *, $P < 0.05$.

Table 9. Dietary survey results (subgroup2).

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
Energy	kcal	Baseline	Rosehip group	24	2490.9	994.3	-	236.1 (–259.4, 731.6)	0.342
			Placebo group	28	2254.7	730.5	-		
		4-week	Rosehip group	24	2299.9	681.7	2223.1 (1924.2, 2522.0)	–209.3 (–617.8, 199.1)	0.308
			Placebo group	28	2385.2	966.6	2432.4 (2156.8, 2708.1)		
		8-week	Rosehip group	24	2347.0	671.8	2281.5 (2050.3, 2512.6)	–75.0 (–394.3, 244.3)	0.639
			Placebo group	27	2289.7	669.6	2356.5 (2139.5, 2573.5)		
		12-week	Rosehip group	24	2321.6	770.7	2212.0 (1835.5, 2588.6)	–328.1 (–847.9, 191.6)	0.211
			Placebo group	27	2428.4	1327.8	2540.1 (2187.1, 2893.2)		
		Δ4-week	Rosehip group	24	–191.0	992.7	–121.6 (–420.5, 177.3)	–209.3 (–617.8, 199.1)	0.308
			Placebo group	28	130.4	648.8	87.7 (–188.0, 363.4)		
		Δ8-week	Rosehip group	24	–143.8	839.5	–63.3 (–294.4, 167.9)	–75.0 (–394.3, 244.3)	0.639
			Placebo group	27	93.2	601.6	11.8 (–205.2, 228.8)		
		Δ12-week	Rosehip group	24	–169.2	942.0	–132.7 (–509.3, 243.9)	–328.1 (–847.9, 191.6)	0.211
			Placebo group	27	232.0	916.4	195.4 (–157.6, 548.5)		
Protein	g	Baseline	Rosehip group	24	100.4	42.5	-	8.9 (–11.2, 29.1)	0.374
			Placebo group	28	91.5	25.5	-		
		4-week	Rosehip group	24	94.7	30.3	92.1 (78.3, 105.8)	–7.1 (–25.9, 11.6)	0.448
			Placebo group	28	97.5	42.0	99.2 (86.5, 111.9)		
		8-week	Rosehip group	24	92.8	25.7	90.6 (80.3, 100.9)	–5.7 (–19.8, 8.5)	0.427
			Placebo group	27	94.0	30.1	96.3 (86.6, 105.9)		
		12-week	Rosehip group	24	88.9	26.3	85.0 (68.2, 101.9)	–15.9 (–39.2, 7.4)	0.176
			Placebo group	27	96.9	59.9	100.9 (85.1, 116.8)		
		Δ4-week	Rosehip group	24	–5.7	43.9	–2.9 (–16.7, 10.8)	–7.1 (–25.9, 11.6)	0.448
			Placebo group	28	6.0	30.7	4.2 (–8.5, 16.9)		
		Δ8-week	Rosehip group	24	–7.7	38.0	–4.4 (–14.7, 5.9)	–5.7 (–19.8, 8.5)	0.427
			Placebo group	27	4.4	25.7	1.2 (–8.4, 10.9)		
		Δ12-week	Rosehip group	24	–11.5	37.1	–10.0 (–26.8, 6.9)	–15.9 (–39.2, 7.4)	0.176
			Placebo group	27	7.3	45.4	5.9 (–9.9, 21.7)		
Lipid	g	Baseline	Rosehip group	24	89.4	40.8	-	10.7 (–8.7, 30.1)	0.270
			Placebo group	28	78.7	24.9	-		

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
		4-week	Rosehip group	24	82.2	32.7	78.8 (65.4, 92.1)	-6.7 (-25.0, 11.6)	0.465
			Placebo group	28	83.2	39.4	85.5 (73.2, 97.8)		
		8-week	Rosehip group	24	85.7	26.3	82.9 (73.7, 92.1)	-0.5 (-13.2, 12.3)	0.942
			Placebo group	27	80.7	26.5	83.4 (74.7, 92.0)		
		12-week	Rosehip group	24	80.6	30.4	76.3 (60.4, 92.1)	-13.3 (-35.3, 8.7)	0.229
			Placebo group	27	85.6	53.3	89.6 (74.7, 104.5)		
		Δ4-week	Rosehip group	24	-7.2	40.0	-4.2 (-17.5, 9.2)	-6.7 (-25.0, 11.6)	0.465
			Placebo group	28	4.5	31.2	2.5 (-9.8, 14.8)		
		Δ8-week	Rosehip group	24	-3.6	35.0	0.0 (-9.2, 9.2)	-0.5 (-13.2, 12.3)	0.942
			Placebo group	27	4.2	20.9	0.4 (-8.2, 9.1)		
		Δ12-week	Rosehip group	24	-8.7	33.3	-6.7 (-22.5, 9.2)	-13.3 (-35.3, 8.7)	0.229
			Placebo group	27	9.0	43.9	6.6 (-8.3, 21.5)		
Carbohydrate	g	Baseline	Rosehip group	24	304.8	125.0	-	26.4 (-38.7, 91.5)	0.418
			Placebo group	28	278.4	105.1	-		
		4-week	Rosehip group	24	279.0	94.6	269.2 (232.0, 306.5)	-27.1 (-77.9, 23.7)	0.289
			Placebo group	28	290.7	124.0	296.3 (262.0, 330.7)		
		8-week	Rosehip group	24	289.6	94.9	281.6 (249.5, 313.7)	-3.0 (-47.3, 41.2)	0.891
			Placebo group	27	275.7	92.1	284.6 (254.5, 314.8)		
		12-week	Rosehip group	24	296.1	118.9	283.1 (237.6, 328.5)	-25.8 (-88.6, 36.9)	0.412
			Placebo group	27	294.7	154.1	308.9 (266.2, 351.6)		
		Δ4-week	Rosehip group	24	-25.8	121.8	-18.7 (-56.0, 18.5)	-27.1 (-77.9, 23.7)	0.289
			Placebo group	28	12.4	80.1	8.3 (-26.0, 42.7)		
		Δ8-week	Rosehip group	24	-15.2	102.2	-6.4 (-38.5, 25.7)	-3.0 (-47.3, 41.2)	0.891
			Placebo group	27	5.3	92.7	-3.3 (-33.4, 26.8)		
		Δ12-week	Rosehip group	24	-8.7	130.4	-4.9 (-50.4, 40.6)	-25.8 (-88.6, 36.9)	0.412
			Placebo group	27	24.2	93.7	20.9 (-21.8, 63.6)		
Dietary fiber	g	Baseline	Rosehip group	24	15.9	6.6	-	2.0 (-1.4, 5.3)	0.240
			Placebo group	28	14.0	5.1	-		
		4-week	Rosehip group	24	14.5	5.4	13.9 (11.9, 15.9)	-1.4 (-4.2, 1.4)	0.327
			Placebo group	28	14.8	6.1	15.3 (13.4, 17.1)		
		8-week	Rosehip group	24	15.6	6.7	14.9 (12.7, 17.1)	-0.3 (-3.3, 2.7)	0.846
			Placebo group	27	14.5	5.6	15.2 (13.1, 17.2)		

Items	Unit	Time point	Group	n	Mean	SD	EMM (95% CI)	Group difference (95% CI)	P value
		12-week	Rosehip group	24	14.7	6.1	13.8 (11.0, 16.5)	−2.1 (−6.0, 1.7)	0.266
			Placebo group	27	14.9	9.5	15.9 (13.3, 18.5)		
		Δ4-week	Rosehip group	24	−1.4	6.8	−0.9 (−2.9, 1.2)	−1.4 (−4.2, 1.4)	0.327
			Placebo group	28	0.9	4.2	0.5 (−1.4, 2.4)		
		Δ8-week	Rosehip group	24	−0.4	6.9	0.2 (−2.0, 2.3)	−0.3 (−3.3, 2.7)	0.846
			Placebo group	27	1.0	4.7	0.4 (−1.6, 2.5)		
		Δ12-week	Rosehip group	24	−1.2	6.6	−1.0 (−3.7, 1.8)	−2.1 (−6.0, 1.7)	0.266
			Placebo group	27	1.3	6.7	1.2 (−1.4, 3.7)		

Data are presented as mean and standard deviation. After the intervention, the estimated marginal mean (EMM) and their 95% confidence interval (CI) are shown. For group differences, the mean difference and its 95% CI are presented at baseline, and the difference in EMMs and its 95% CI are shown after the intervention. 4-week, after the 4-week intervention; 8-week, after the 8-week intervention; 12-week, after the 12-week intervention; Δ, change from baseline.

DISCUSSION

This study investigated the effects of consuming a test food containing 100 mg of rosehip extract on abdominal VFA in healthy Japanese adults with a BMI ≥ 25 and < 30 kg/m². There was no significant difference in abdominal VFA at baseline. However, at the 12-week intervention, the measured values and changes from baseline in abdominal VFA were significantly lower in the rosehip group compared with the placebo group. Furthermore, although both groups started with a similar baseline VFA (mean: 102.3 cm² for the rosehip group and 100.7 cm² for the placebo group), the EMM of abdominal VFA at 12-week intervention was 93.5 cm² in the rosehip group and 102.8 cm² in the placebo group. At 12 weeks, the adjusted EMM of abdominal VFA was below 100 cm² in the rosehip group and above 100 cm² in the placebo group; these values should be interpreted as adjusted group means rather than as individual achievement of the clinical threshold.

According to the Japan Society for the Study of Obesity, obesity is a condition characterized by abnormal or excessive fat accumulation in adipose tissue, defined by a BMI ≥ 25 kg/m² [25]. Obesity is considered a risk factor for various lifestyle-related diseases, including diabetes, kidney disease, dyslipidemia, hypertension, and cardiovascular disease [26]. Furthermore, an abdominal VFA ≥ 100 cm² is the diagnostic criterion for visceral obesity [25], which is associated with an increased mean number of obesity-related cardiovascular risk factors—such as hypertension, dyslipidemia, and hyperglycemia—in Japanese individuals [8,27]. Moreover, the number of risk factors positively correlates with abdominal VFA, meaning that a lower abdominal VFA corresponds to fewer risk factors [8]. Therefore, the reduction in abdominal VFA to levels below 100 cm² observed after 12 weeks of consuming foods containing rosehip extract may contribute to improving this risk-related marker in healthy individuals with a BMI ≥ 25 kg/m² and < 30 kg/m².

Tiliroside, which is present in the foods containing

rosehip extract used in this study, is a type of acylated flavonol glycoside that has been shown to affect glucose and lipid metabolism in hepatoblastoma-derived HepG2 cells [28]. Additionally, in experiments using normal mice, tiliroside inhibited weight gain and abdominal visceral fat accumulation, and increased the hepatic mRNA expression of peroxisome proliferator-activated receptor alpha (PPAR- α), which is involved in lipid metabolism [12]. Furthermore, in an obese diabetic mouse model, tiliroside reduced plasma free fatty acids and triglycerides, increased plasma adiponectin concentrations, upregulated the mRNA expression of adiponectin receptors in the liver and skeletal muscle, activated AMP-activated protein kinase (AMPK) in the liver and skeletal muscle, activated hepatic PPAR- α , and suppressed triglyceride accumulation in the liver and skeletal muscle [29]. The suggested mechanism for these effects involves improved lipid metabolism through increased fatty acid oxidation, driven by the activation of adiponectin signaling via both AMPK and PPAR- α . Therefore, we hypothesize that consuming foods containing rosehip extract modulates lipid metabolism through this mechanism and suppresses visceral fat accumulation.

Human pharmacokinetic data on tiliroside remain limited, partly because the intact compound appears to have low intestinal absorption. Although *in vitro* studies using Caco-2 cells suggest that efflux transporters may contribute to its limited permeability, interactions within multicomponent matrices and formulation strategies may improve oral absorption [30–31]. Comprehensive *in vivo* studies are therefore needed to characterize the absorption, distribution, metabolism, and elimination of tiliroside and to determine the contribution of its potentially bioactive metabolites.

A subgroup analysis was performed on participants whose baseline abdominal VFA was less than 100 cm². The results showed that abdominal VFA and abdominal TFA were significantly lower in the rosehip group after the 12-

week intervention, suggesting that the intake of foods containing rosehip extract could inhibit abdominal visceral fat accumulation even in overweight individuals with baseline VFA below the visceral obesity threshold.

In the overall analysis, no significant between-group differences were observed for the other outcomes described below. However, the rosehip group had a lower abdominal TFA than the placebo group after the 12-week intervention. Body fat percentage was significantly lower, and lean mass was significantly higher in the rosehip group compared with the placebo group after the 4-week intervention. The primary finding supports an effect on abdominal VFA, whereas the observed body-composition differences were limited to selected secondary outcomes and should be interpreted cautiously.

In Japanese individuals, abdominal visceral and subcutaneous fat areas are positively correlated with hypertension, blood glucose levels, and triglycerides, and negatively correlated with HDL cholesterol [32]. Therefore, managing not only abdominal visceral fat but also abdominal subcutaneous fat is crucial for maintaining overall health. However, unlike the significant reduction in abdominal VFA observed in the rosehip group, no significant difference was observed in abdominal SFA between the groups. Abdominal visceral fat cells are metabolically more active than abdominal subcutaneous fat cells, possess greater sensitivity to lipolysis [33], and exhibit a higher reduction rate than subcutaneous fat in response to interventions [34]. Thus, in the present study, it is plausible that the effects of the foods containing rosehip extract were more readily reflected in abdominal VFA than in abdominal SFA. Considering the mechanism underlying the body fat-reducing effect of foods containing rosehip extract, and because this effect is not limited to abdominal visceral fat, future clinical trials using abdominal SFA as an allocation factor are needed to clarify the effects of these foods on abdominal subcutaneous fat.

In this study, favorable results were observed

regarding the effects of consuming foods containing rosehip extract on abdominal visceral fat. Importantly, this trial provides additional clinical evidence of the visceral fat-reducing effect of rosehip-derived tiliroside in overweight Japanese individuals and strengthens the reproducibility and robustness of the existing evidence through an improved study design incorporating an a priori sample size calculation based on previous findings and appropriate consideration of multiplicity. However, caution is warranted when interpreting these findings in light of the dietary survey results. Although no significant differences were observed between the groups in the total reference nutritional values from the 9-day dietary survey (pooled data from all postintervention assessments; data not shown), several items were significantly lower in the rosehip group than in the placebo group during certain postintervention assessments. It has been reported that certain rosehip species improve constipation [35]. Therefore, it is possible that the rosehip extract influenced gastrointestinal function, thereby affecting dietary intake. In addition, although derived from petals rather than fruits, rose petal extract has been reported to exert appetite-suppressing effects [36], and this potential mechanism warrants further investigation. However, the dietary survey was conducted for only three days prior to each examination day, and the composition of the intervention used in the study by Sudeep et al. [36] differed from that of the foods containing rosehip extract in our study. Therefore, it remains unclear whether they produce similar effects, warranting caution when interpreting the results of the present study. To properly evaluate whether foods containing rosehip extract reduce abdominal VFA through appetite suppression in future studies, researchers must account for the short duration of the dietary survey used in this study. Future designs should incorporate a dietary survey that covers the entire study period while simultaneously assessing appetite using a VAS [37-38], or otherwise be structured to minimize dietary bias among

participants.

Regarding postintervention safety, no adverse events were observed during the study period (data not shown). However, when examining the proportion of participants whose urinalysis and peripheral blood test results were within normal ranges at baseline but fell outside those ranges postintervention, significant differences were observed between the groups for certain peripheral blood test parameters. These differences were considered clinically insignificant by the principal physician and were not associated with any medical concerns, representing only transient and negligible changes. This interpretation is supported by our previous *in vitro*, *in vivo*, and clinical studies evaluating the safety of the same rosehip extract powder in healthy individuals, all of which revealed no medically significant changes [39-40]. Furthermore, although several premeasurement conditions were controlled, water intake was not restricted or recorded, and caffeine intake, bladder emptying, and the time of day of body composition measurements were not specifically standardized. Because bioelectrical impedance analysis is sensitive to hydration status and other measurement conditions, these factors may have introduced variability into the body composition measurements.

Scientific Innovation and Practical Implications: This study provides further clinical evidence that rosehip-derived tiliroside may reduce abdominal visceral fat area (VFA), with exploratory subgroup findings suggesting a similar effect in individuals with baseline VFA below the visceral obesity threshold of 100 cm². Furthermore, by employing an a priori sample size estimation and specifying abdominal VFA as the primary outcome, this study fulfills the rigorous clinical evaluation steps outlined in the Functional Food Development Framework established by the Functional Food Center (FFC) [17]. This methodological refinement bridges foundational bioactive research and successful

clinical validation, thereby supporting the potential role of tiliroside as a scientifically substantiated food-derived ingredient for abdominal fat management and facilitating its future standardization and public health application [17]. Future research should focus on clarifying the underlying metabolic pathways and investigating long-term impacts on body composition.

CONCLUSIONS

This study examined the effects of consuming a test food containing 100 mg of rosehip extract on abdominal VFA in healthy Japanese adults with a BMI ≥ 25 and < 30 kg/m². The results showed that following the 12-week intervention, abdominal VFA, the primary outcome, was significantly lower in the rosehip group than in the placebo group. Additionally, after the 4-week intervention, body fat percentage and fat mass were significantly lower, while lean mass and muscle mass were significantly higher in the rosehip group compared with the placebo group. These findings suggest that consuming a test food containing 100 mg of rosehip extract can inhibit abdominal visceral fat accumulation and influence body composition. Furthermore, this inhibitory effect on abdominal visceral fat accumulation was confirmed even in individuals with an abdominal VFA below 100 cm².

Abbreviations: 95% CI: 95% confidence interval; AMPK: AMP-activated protein kinase; BMI: body mass index; CAND: Calorie and Nutrition Diary; CRO: contract research organization; EMM: estimated marginal mean; FAS: full analysis set; Max: maximum; Med: median; Min: minimum; NA: not available; PPAR- α : peroxisome proliferator-activated receptor alpha; Q1: first quartile; Q3: third quartile; SD: standard deviation; SFA: subcutaneous fat area; TFA: total fat area; VFA: visceral fat area.

Competing interests: This study was conducted by Morishita Jintan Co., Ltd., to which N.N., A.N., and M.K.

belong, and this company bore all the costs related to the administration of the study and the writing of the paper. N.S. is affiliated with ORTHOMEDICO Inc., the CRO contracted by Morishita Jintan Co., Ltd. to conduct this study. T.T. is the principal physician (MD) affiliated with Medical Corporation Seishinkai, Takara Clinic, which ORTHOMEDICO Inc. contracted to conduct the study. All expenses related to the study were paid to Takara Clinic through ORTHOMEDICO Inc. In addition, the principal physician has no ownership interest in any company involved in the research and has not received any honoraria or research grants separate from the costs of conducting the study. Moreover, the authors declare no other personal or non-financial conflicts of interest that could influence the findings of this study.

Data Availability Statement: The datasets generated and/or analyzed during the current study are not publicly available due to ethical restrictions regarding participant privacy and the original terms of informed consent. However, de-identified data are available from the corresponding author on reasonable request, subject to approval by the Institutional Review Board and the execution of a formal Data Sharing Agreement.

Authors' contributions: Conceptualization, M.K. and N.S.; Data curation, N.S.; Formal analysis, N.S.; Funding acquisition, M.K.; Investigation, N.S. and T.T.; Methodology, N.N., A.N., M.K., and N.S.; Project administration, M.K. and N.S.; Resources, N.N.; Supervision, T.T.; Visualization, N.N., A.N., and N.S.; Writing—original draft preparation, N.N., A.N., M.K., and N.S.; Writing—review and editing, N.N., A.N., M.K., N.S., and T.T.

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