Archives of Clinical Trials

Original Article

The Effect of the Timing of Banana Intake on Postprandial Glucose Spike: Randomized Parallel-Group Comparison Study

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- Received Date: 04 Sep 2023
- Accepted Date: 11 Sep 2023
- Publication Date: 13 Sep 2023

Keywords: banana at breakfast, glucose metabolism, glycoalbumin, post-prandial glucose spike

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Abstract

Objective: *To elucidate the effects of the timing of banana intake on postprandial glucose spike and glucose metabolism.*

Methods: *This randomized parallel-group comparison study was designed to randomize 54 adults aged 41- 60 years into three groups. The first group consumed 120 g of banana at breakfast daily for 2 weeks, the second group consumed 120 g of banana after dinner daily for 2 weeks, and the third consumed no banana or banana-containing food for 2 weeks. The participants in each group wore a continuous glucose monitor on their arms for 2 weeks to measure their blood glucose trend. Body composition and serum biomarkers were evaluated before and after intervention.*

Results: *There were 16 participants in the banana-at-breakfast group, 16 in the banana-after-dinner group, and 15 in the control group. We defined a postprandial blood glucose increase of >140 mg/dL as a "glucose spike." When comparing the glucose spike incidence ratio (incidence of glucose spikes divided by number of times measured), the point estimate of the incidence ratio of banana-at-breakfast group at dinner compared with breakfast was 1.55 (point estimate. 95% confidence interval: 1.09-2.20), that of banana-after dinner group 1.83 (point estimate. 95% confidence interval: 1.28-2.61), and control group 2.03 (point estimate. 95% confidence interval: 1.36-3.04). In addition, the banana-after-dinner and control groups showed a higher incidence ratio, compared with the banana-at-breakfast group. Glycoalbumin decreased significantly in the banana-at- breakfast group compared with the other groups.*

Conclusions: *The results showed that glucose spikes were less generated when consuming bananas at breakfast than when consuming them after dinner or not consuming them at all. The level of glycoalbumin, an index for average blood glucose, was lower in the banana-at-breakfast group than in the banana-after-dinner and control groups within 2 weeks.*

Clinical Trial Registry*: UMIN 000050025*

Introduction

Banana is a common fruit frequently consumed by the Japanese people, as it is readily accessible and affordable, ranked first among all fruits in terms of annual consumption in a survey in 2020 [1]. Studies on the health effects of banana, epidemiological and clinical studies in humans, and basic researches have progressed, with an increasing number of studies suggesting banana's benefits for human health [2–5]. Furthermore, several studies on blood glucose changes after banana consumption conducted in many countries have reported that blood glucose level after consuming banana is not so high and that the sugar content of the fruit, which is generally considered sweet, is not high [6]. "Postprandial blood glucose spike" is not strictly a medical term; however, it refers to a sudden rise in blood glucose levels during approximately 2 h after consumption of a certain food, and several studies have been conducted on blood glucose fluctuations after consumption various foods, when examining the risk of diabetes incidence and deterioration and the risk of cardiovascular disease [7–9]. Generally, consumers seem to consider banana a sweet fruit, and some believe that eating bananas may cause a sudden rise in blood glucose levels, resulting in a blood glucose spike; however, studies on glucose spikes after banana consumption in Japanese people are limited [10–15].

This study aimed to investigate the frequency of postprandial blood glucose spikes, glucose metabolism, and changes in body composition, blood pressure, and blood biochemical parameters in adults consuming bananas for approximately two consecutive weeks, according to the timing of banana consumption at breakfast and after dinner.

Citation: Itoh M, Inoue H. The Effect of the Timing of Banana Intake on Postprandial Glucose Spike: Randomized Parallel-Group Comparison Study. Arch Clin Trials. 2023;3(1):1-8.

Materials and methods

Ethical considerations

This study was conducted in accordance with the ethical principles based on the Declaration of Helsinki and the Ethical Guidelines for Medical Research Involving Human Subjects (Ministry of Health, Labor and Welfare, 28 February 2017) and in compliance with the study protocol. Approval was obtained from the Healthcare Systems Ethics Committee (20 December 2022; IRB No. 17000069), and the UMIN study ID in the public database set up by the University Hospital Medical Information Network Centre (UMIN-CTR) was UMIN 000050025. In addition, this study conformed to the CONSORT 2010 statement.

Study participants

Participant recruitment and management and study implementation were conducted by Healthcare Systems Inc, and volunteers who met the selection criteria using a self-reporting system were eligible to participate in this study. This study was conducted at Akasaka Family Clinic in Tokyo between January and February 2022. Continuous blood glucose monitoring was conducted at home or other locations of the study participants, measured by the participants themselves after receiving thorough instructions at the clinic. The study participants were provided with a written explanation and consent document explaining the study's purpose, content, and methods, and their written voluntary consent was obtained.

The selection criteria were as follows: age of 41–60 years and presence of no apparent disease. The exclusion criteria were (1) presence of any disease requiring treatment, as judged by the supervising physician, (2) severe anemia, (3) pregnancy, lactation, or expecting lactation, (4) potential to develop allergic symptoms to the ingredients in the test food, (5) alcohol dependency or other mental disorders, (6) a smoking habit (7) borderline diabetes or diagnosis of diabetes, fasting blood glucose level ≥110 mg/dl, HbA1c ≥6.5%, or blood glucose level ≥140 mg/dl at 2 h of 75 g oral glucose tolerance test, (8) potential to change lifestyle during the study period, (9) risk of developing seasonal allergy symptoms such as hay fever during the study period, (10) intention to consume new healthy foods or use food supplements during the study period, (11) a history of hormone replacement therapy within the past 6 months, (12) a history of treatment involving hospitalization within the past 6 months, (13) Scheduled for X-ray, magnetic resonance imaging (MRI), computed tomography (CT), scan or other tests during the continuous blood glucose monitoring period, (14) current participation in another human clinical trial, <3 months after participating in another human clinical trial, or scheduled for participation in another trial after consenting to the present study, (15) a history of contact dermatitis or risk of developing contact dermatitis, and (16) presence of any other disease as judged by the investigator to be unsuitable for this study.

This study was designed as a randomized, single-blind, parallel-group trial, and 54 male and female volunteers aged between 41 and 60 years were recruited. Before the intervention, study participants underwent blood tests, physical measurements, and blood pressure tests. Blood tests were performed and randomized between the three study groups in blocks according to sex and fasting blood glucose results to avoid differences in glucose metabolism condition. The study duration was set at 2 weeks because that was the maximum continuous wearing period of the continuous arm-worn blood glucose monitor system.

Tests

Regular bananas (dessert bananas), Cavendish from the Philippines were used as the test food, the ripeness being 5 out of ripeness scale of 1 (green) to 7 (fully ripe), and the nutritional composition of the test food is presented in Table 1. The continuous blood glucose mete was the Freestyle Libre (Abbott Diabetes Care Inc., US). The monitor was attached on the back side of the non-dominant arm of the participant, after receiving instructions about the attachment at the clinic.

Group A (banana-at-breakfast group) consumed approximately 120 g of banana at the beginning of breakfast daily for 2 weeks, with no restrictions on their meal in terms of content or timing. All study participants had a continuous blood glucose monitor on their arm for 2 weeks, and glucose measurements were performed at least before the meal and 30 min, 1 h, and 2 h after breakfast. Group B (banana-after-dinner group) consumed approximately 120 g of banana after dinner daily for 2 weeks, with no restrictions on their meal in terms of content or timing. All study participants had a continuous blood glucose monitor on their arm for 2 weeks, and glucose measurements were

Table 1. *Nutritional content of the test food*

Nutrition Item	Content
Energy	112 kcal
Protein	1.32 g
Lipids	0.24 g
Carbohydrate	27 g
(dietary fiber, included in carbohydrate)	(1.32 g)
Salt equivalent	0 g
Sodium	Tr mg
Potassium	432 mg
Calcium	7.2 mg
Magnesium	38.4 mg
Phosphorus	32.4 mg
Iron	0.36 mg
Zinc	0.24 mg
Copper	0.11 mg
Manganese	0.31 mg
Selenium	1.2 μg
Molybdenum	8.4 μg
β carotene equivalent	67.2 μg
α tocopherol	0.6 mg
Vitamin B1	0.06 mg
Vitamin B2	0.05 mg
Niacin equivalent	1.08 μg
Vitamin B6	0.46 mg
Folic acid	31.2 μg
Pantothenic acid	0.53 mg
Biotin	1.68 μg
Vitamin C	19.2 mg
(Source: Standard Tables of Food Composition in Japan 2022, 8th Revised Version Uncooked banana daily intake (120 g)	

performed at least before the meal and 30 min, 1 h, and 2 h after dinner.

The control group (no banana group) had no banana intake for 2 weeks, with no restrictions on their meal in terms of content or timing.

All the participants were required to record their diet and exercise during the 2 weeks.

Outcomes

The primary endpoint was the frequency of postprandial blood glucose spikes measured using a continuous glucose monitoring system. "Postprandial blood glucose spike" was defined as a "spike" if it exceeded 140 mg/dL at 30 min, 1 h, or 2 h after a meal.

Secondary endpoints included fasting blood indices (total protein, albumin, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, triglycerides, urea nitrogen, creatinine, uric acid, aspartate aminotransferase, alanine aminotransferase, hemoglobin A1C (HbA 1C), glucose, glycoalbumin, 1,5-anhydroglucitol, insulin, sodium, potassium, chloride, calcium, magnesium, inorganic phosphorus, serum iron, blood count, and ferritin), physical examination findings (weight and body mass index [BMI]), blood pressure (systolic and diastolic), and pulse rate.

Blood tests were performed in the laboratory of SRL Ltd (Shinjuku Mitsui Building 10F, 1-1, Nishi- Shinjuku 2-chome, Shinjuku-ku, Tokyo). Fasting blood indices, physical examination parameters, blood pressure, and subjective findings were recorded by each participant in a diary, and other findings were obtained during an interview with the supervising physician to determine adverse events during the study period.

Statistical analysis

Blood glucose spike incidence ratios were estimated using Poisson regression, and statistical analyses of blood pressure, physical examination parameters (weight and BMI), blood counts, and blood biochemistry test values were performed using Student t-test, correspondence t-test, Wilcoxon signed-rank test, and Welch's test on each test value before and after the intervention. Statistical significance was set at P = 0.05 (two-tailed). Statistical analyses were performed using SAS (SAS Institute Inc., US), STATA ver. 17 (STATA Corp. LLC., US).

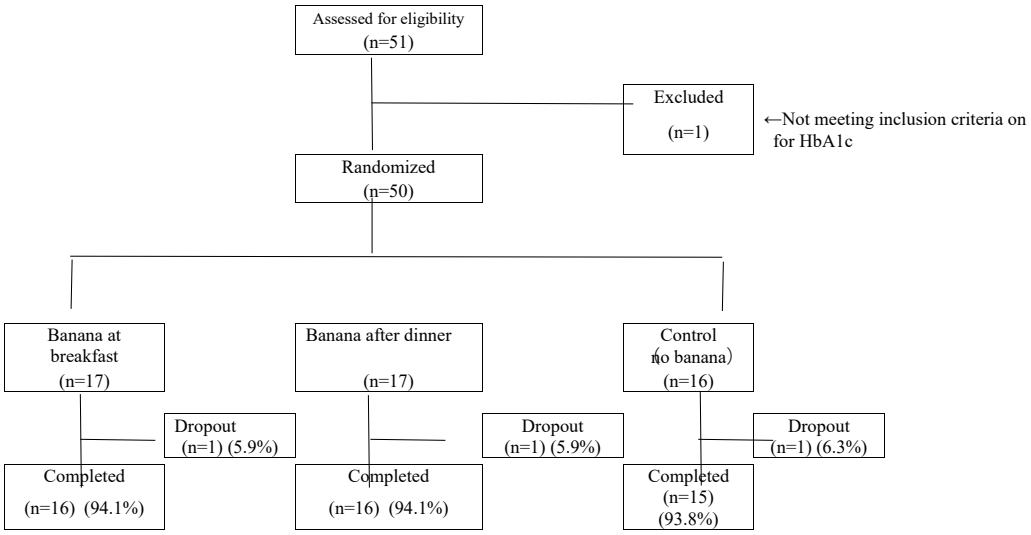

***Figure 1**. Study flow diagram*

***Table 2**. Participant baseline characteristics*

	Banana at breakfast	Banana after dinner	Control (no banana)	Inter-group comparison
	(n =16)	(n = 16)	(n = 15)	
Sex	M 7(43.75%)	7(43.75%)	7(46.67%)	0.98
	F 9(56.25%)	9(56.25%)	8(53.33%)	
Age	49.00±4.95	49.63±4.87	48.87±5.67	0.91
Height (cm)	159.96±7.17	162.63±8.82	163.47±6.72	0.41
BMI	25.11±5.09	22.50±2.59	22.87±3.74	0.14
Weight (kg)	64.85±16.44	59.71±10.18	61.23±11.50	0.52

Average ± standard deviation

Inter-group comparison shows P value.

Categorical variable analyzed with χ^2test, continuous variable with ANOVA

Results

In total, 54 men and women aged 41-60 years who gave written consent to participate (Table 2) were enrolled into the study, of whom 51 were included in the intervention study; however, one participant whose pre-intervention HbA1c test result met the exclusion criteria was excluded. Therefore, the study began with 50 participants. Furthermore, three participants dropped out after the trial started, leaving 47 men and women to complete the trial (Figure 1). No participants were stopped from continuing the trial by the responsible physician after the trial started.

The 47 participants in this study wore the continuous glucose meter for 10–13 days. The device was encouraged to be worn for 14 days whenever possible; however, none of the participants could wear the device for 14 days due to the device being detached from the arm when changing clothes or for other reasons. No skin symptoms due to contact dermatitis or other skin conditions developed. Blood glucose spikes were observed and recorded using the continuous glucose meter until approximately 120 min after a meal, and the incidence ratio of blood glucose spikes was estimated from the number of times each study participant measured their glucose level on the continuous glucose meter and the occurrence of blood glucose spikes. The comparison of postprandial blood glucose spikes among the three groups was analyzed according to incidence, and the results are shown in Table 3. The number of measurements taken and the time they were taken were not uniform because the participants took the measurements according to their daily routines and some forgot to take them or could not take them due to work and other factors. However, based on the number of measurements recorded, the incidence ratios of blood glucose spikes at breakfast and dinner were 0.10 and 0.16, 0.10 and 0.18, and 0.08 and 0.17 in the banana-at-breakfast, banana-at-dinner, and no banana groups, respectively. The point estimate of the incidence ratio of blood glucose spikes at dinner with respect to breakfast was 1.55 (95% confidence interval 1.09-2.20, P = 0.01) in the banana-at- breakfast group, 1.83 (95% confidence interval 1.28-2.61, P<0.01) in the banana-after-dinner group, and 2.08 (95% confidence interval 1.36-3.04, P<0. 10) in the no banana group.

The results of the pre- and post-intervention comparisons of body composition and blood pressure tests are shown in Table 4. There were no significant changes in body weight, BMI, or blood pressure in the three groups before and after the intervention.

The results of pre- and post-intervention comparisons of blood counts and biochemical tests are shown in Table 5. After the intervention, HbA1c levels increased in the banana-at-dinner and no banana groups (P<0.01 and P<0.01, respectively); glycoalbumin levels decreased in the banana-at-breakfast group (P<0.01); potassium levels increased in the banana-at-breakfast group (P<0.01) and were higher in the banana-at-breakfast group than in the banana-at-dinner group (P=0.01); chlorine levels increased in the banana-at-dinner group (P=0.04); calcium levels decreased in the banana-at-dinner group (P=0.02); magnesium levels decreased in the banana-at-dinner and no banana groups (P=0.03, P=0.02); and inorganic phosphorus levels increased in the banana-at-dinner group (P=0.01).

In addition, white blood cell count decreased in the no banana group (P<0.01); Hb and hematocrit levels decreased in the banana-at-dinner group (P=0.03 and P<0.01, respectively); and mean corpuscular volume (MCV) decreased in all three groups (P=0.04, P=0.04, and P=0.03, respectively), in pre- and post-intervention comparisons.

No serious adverse events occurred during the study. Contact dermatitis symptoms such as itching and sores on the skin are common in clinical practice when wearing continuous glucose meters; however, none occurred in the present clinical study.

Discussion

Bananas are an easy-to-eat favorite fruit of Japanese people of all ages, and research into their health benefits is ongoing.

Notably, 100 g of banana contains 93 kcal (53 kcal for apple) and 18.5 g of available carbohydrate (total of starch, glucose, fructose, sucrose, maltose, lactose, and trehalose) (12.2 g for

***Table 3**. Comparison of glucose spike (analysis per incidence)*

		Breakfast			Dinner			Incidence rate at dinner compared to breakfast		Incidence rate ratio between no banana group at breakfast		Incidence rate ratio at dinner compared to no banana group	
Groups	n	glucose spike frequency	number of measurements	incidencerate ratio frequency of spike/measured times	glucose spike frequency	number of measurements	incidencerate ratio frequency of spike/measured times	point estimate (95% confidence interval)	P value	point estimate (95% confidence interval)	P value	point estimate (95% confidence interval)	P value
Banana at breakfast	16	54	519	0.1	75	465	0.16	1.55 (1.09 ~ 2.20)	0.01	1.23 (0.80 ~ 1.87)	0.34	0.93 (0.67 ~ 1.29)	0.68
Banana after dinner	16	46	466	0.1	89	494	0.18	1.83 (1.28 ~ 2.61)	<0.01	1.16 (0.75 ~ 1.80)	0.5	1.04 (0.76 ~ 1.42)	0.79
Control (no banana)	15	36	424	0.08	71	411	0.17	2.03 (1.36 ~ 3.04)	<0.01	-	-	-	-

Number of glucose spike: Count as ONE when post-prandial glucose is higher than 140mg/dL at 30 minutes after meal, 1hour after meal, or at 2 hours after meal. .Incidence ratio estimated by Poisson RegressionP

Table 4. *Body composition and blood pressure comparison among groups*

	Pre-intervention			Post-intervention			Pre vs post			Between groups		
	Group A: Banana at breakfast	Group B: Banana after dinner	Group C: Control (no banana)	Group A: Banana at breakfast	Group B: Banana after dinner	Group C: Control (no banana)	Group A: Banana at breakfast	Group B: Banana after dinner	Group C: interventi Control (no banana)	Post intervention Group A Vs control	Post intervention Group B Vs control	Post intervention Group A Vs Group B
	(n=16)	(n=16)	(n=15)	(n=16)	(n=16)	(n=15)						
BMI	25.11 ± 5.09	22.50 ± 2.59	22.87 ± 3.74	24.94 ± 4.96	22.45 ± 2.56	22.57 ± 3.51	0.11	0.51	0.04	0.14	0.92	0.08
Body weight (kg)	64.85 ± 16.44	59.71 ± 10.18	61.23 ± 11.50	64.46 ± 16.07	59.77 ± 10.25	60.56 ± 11.18	0.14	0.75	0.07	0.44	0.84	0.33
Systolic blood pressure (mmHg)	117.78 ± 20.59	116.06 ± 18.03	118.60 ± 16.92	121.56 ± 17.26	114.13 ± 12.20	116.87 ± 15.84	0.1	0.66	0.58	0.44	0.59	0.17
Diastolic blood pressure (mmHg)	77.00 ± 16.62	73.69 ± 9.98	72.00 ± 12.31	76.84 ± 14.64	73.03 ± 9.80	76.53 ± 12.30	0.93	0.62	0.05	0.95	0.39	0.39

±Standard deviation

Pre and post intervention c omparison in P value , comparison among groups in P value

Pre and post intervention c omparison analyzed with paired t test , comparison among groups with ANOVA

Table 5. *Results of blood count test and blood biochemical parameters*

	Pre-intervention			Post-intervention			Pre vs post			Between groups		
	Group A: Banana at breakfast (n=16)	Group B: Banana after dinner (n=16)	Group C: Control (no banana) (n=15)	Group A: Banana at breakfast (n=16)	Group B: Banana after dinner (n=16)	Group C: Control (no banana) (n=15)	Group A: Banana at breakfast	Group B: Banana after dinner	Group C: interventi Control (no banana)	Post intervention Group A Vs control	Post intervention Group B Vs control	Post intervention Group A Vs Group B
Total protein (g/dL)	7.21 ± 0.28	7.48 ± 0.34	7.43 ± 0.47	7.19 ± 0.21	7.29 ± 0.30	7.36 ± 0.40	0.86	0.06	0.43	0.16	0.61	0.29
Albumin (g/dL)	4.61 ± 0.29	4.74 ± 0.25	4.63 ± 0.30	4.61 ± 0.23	4.61 ± 0.28	4.65 ± 0.21	0.87	0.08	0.84	0.61	0.71	0.95
Total cholesterol (mg/dL)	228.31 ± 35.57	224.75 ± 30.39	225.53 ± 31.76	228.69 ± 31.63	224.44 ± 26.32	220.53 ± 43.69	0.94	0.96	0.42	0.55	0.76	0.68
LDL cholesterol (mg/dL)	143.25 ± 32.56	137.06 ± 31.09	130.93 ± 27.45	140.13 ± 29.27	135.94 ± 27.24	128.07 ± 31.74	0.58	0.82	0.53	0.28	0.46	0.68
HDL cholesterol (mg/dL)	69.56 ± 18.38	72.31 ± 16.61	72.60 ± 22.05	71.00 ± 19.33	70.44 ± 18.34	72.27 ± 24.31	0.27	0.35	0.84	0.87	0.81	0.93
Triglyceride (mg/dL)	84.38 ± 32.00	92.00 ± 56.83	110.33 ± 80.33	99.56 ± 45.83	99.88 ± 61.60	107.93 ± 73.69	0.09	0.57	0.84	0.7	0.74	0.99
Blood urea nitrogen (mg/dL)	13.94 ± 4.43	13.86 ± 4.10	14.86 ± 4.11	14.55 ± 4.43	13.85 ± 3.74	13.75 ± 3.07	0.39	0.99	0.16	0.56	0.93	0.63
Creatinine (mg/dL)	0.74 ± 0.16	0.72 ± 0.12	0.71 ± 0.16	0.74 ± 0.17	0.72 ± 0.14	0.71 ± 0.18	0.8	1	0.83	0.66	0.89	0.72
Uric acid (mg/dL)	5.14 ± 1.43	4.83 ± 1.24	4.83 ± 1.59	5.18 ± 1.49	5.08 ± 1.32	4.80 ± 1.60	0.83	0.22	0.87	0.5	0.6	0.83
Aspartate aminotransaminase (AST) (U/L)	25.19 ± 10.24	22.88 ± 5.44	21.40 ± 4.24	25.25 ± 9.43	22.75 ± 5.29	20.60 ± 3.85	0.92	0.89	0.34	0.09	0.21	0.36
Alanine transaminase (ALT) (U/L)	26.19 ± 20.76	23.44 ± 16.98	20.53 ± 12.14	25.00 ± 17.47	23.75 ± 14.54	19.27 ± 12.13	0.32	0.82	0.62	0.3	0.36	0.83
HbA1C (%)	4.96 ± 0.25	4.99 ± 0.15	4.99 ± 0.30	5.02 ± 0.24	5.09 ± 0.19	5.11 ± 0.30	0.12	<0.01	<0.01	0.37	0.89	0.34
Glucose (mg/dL)	88.00 ± 5.07	88.81 ± 8.81	86.87 ± 7.96	86.81 ± 5.29	86.50 ± 8.52	86.80 ± 4.87	0.29	0.2	0.98	0.99	0.91	0.9
Glycoalbumin (%)	12.93 ± 1.74	13.31 ± 1.03	13.76 ± 1.43	12.79 ± 1.70	13.19 ± 1.07	13.60 ± 1.34	<0.01	0.16	0.13	0.16	0.36	0.43
1,5AG (□/mL)	18.64 ± 5.58	19.69 ± 7.97	20.13 ± 8.31	18.94 ± 5.87	19.56 ± 7.89	20.54 ± 8.35	0.2	0.56	0.31	0.54	0.74	0.8
Insulin (μIU/mL)	6.98 ± 5.81	6.41 ± 6.62	5.67 ± 3.82	8.11 ± 5.49	6.08 ± 3.02	6.82 ± 4.36	0.05	0.81	0.12	0.48	0.59	0.2

	Pre-intervention			Post-intervention			Pre vs post			Between groups		
	Group A: Banana at breakfast (n=16)	Group B: Banana after dinner (n=16)	Group C: Control (no banana) (n=15)	Group A: Banana at breakfast (n=16)	Group B: Banana after dinner (n=16)	Group C: Control (no banana) (n=15)	Group A: Banana at breakfast	Group B: Banana after dinner	Group C: interventi Control (no banana)	Post intervention Group A Vs control	Post intervention Group B Vs control	Post intervention Group A Vs Group B
Sodium (mEq/L)	139.44 ± 1.50	138.88 ± 1.93	138.40 ± 1.59	139.81 ± 1.68	139.31 ± 1.35	139.13 ± 1.30	0.29	0.32	0.08	0.22	0.71	0.36
Potassium (mEq/L)	4.68 ± 0.42	4.59 ± 0.46	4.81 ± 0.57	4.98 ± 0.27	4.68 ± 0.36	4.97 ± 0.49	0.01	0.37	0.21	0.92	0.07	0.01
Chloride (mEq/L)	103.94 ± 1.69	103.06 ± 2.08	103.47 ± 2.42	104.19 ± 1.76	104.06 ± 1.77	104.73 ± 1.62	0.47	0.04	0.07	0.38	0.28	0.84
Calcium (mg/dL)	8.99 ± 0.26	9.23 ± 0.30	9.08 ± 0.39	8.96 ± 0.28	9.05 ± 0.24	9.02 ± 0.21	0.56	0.02	0.48	0.52	0.72	0.35
Magnesium (mg/dL)	2.26 ± 0.15	2.28 ± 0.14	2.26 ± 0.11	2.27 ± 0.14	2.21 ± 0.11	2.19 ± 0.13	0.68	0.03	0.02	0.1	0.56	0.22
Phosphorous (mg/dL)	3.28 ± 0.47	3.33 ± 0.47	3.28 ± 0.47	3.37 ± 0.36	3.56 ± 0.44	3.35 ± 0.47	0.4	0.01	0.38	0.92	0.21	0.18
Serum iron (□/dL)	122.19 ± 49.22	108.75 ± 44.45	94.67 ± 41.08	115.75 ± 28.60	99.38 ± 23.84	94.27 ± 45.65	0.56	0.39	0.97	0.12	0.7	0.09
White blood cell count (/μL)	6093.75 ±	5637.50 ±	5693.33 ±	5650.00 ±	4887.50 ± 736.55	4966.67 ± 843.18	0.19	0.06	<0.01	0.1	0.78	0.05
Red blood cell count (×104/μL)	465.94 ± 56.45	460.25 ± 35.48	459.60 ± 54.94	472.94 ± 55.06	446.25 ± 46.93	463.33 ± 53.16	0.17	0.06	0.43	0.63	0.35	0.15
Hemoglobin (g/dL)	14.14 ± 1.39	14.04 ± 1.08	14.03 ± 1.87	14.29 ± 1.33	13.62 ± 1.28	14.09 ± 1.88	0.33	0.03	0.72	0.72	0.42	0.15
Hematocrit (%)	43.18 ± 3.99	43.11 ± 2.62	42.90 ± 4.65	43.36 ± 3.67	41.38 ± 3.53	42.69 ± 4.47	0.62	<0.01	0.62	0.65	0.37	0.13
MCV (fL)	93.05 ± 4.30	93.83 ± 3.99	93.70 ± 7.38	92.08 ± 4.34	92.96 ± 3.70	92.40 ± 6.24	0.04	0.04	0.03	0.87	0.76	0.54
MCH (pg)	30.47 ± 1.31	30.56 ± 1.40	30.60 ± 3.09	30.33 ± 1.31	30.58 ± 1.24	30.43 ± 2.82	0.36	0.86	0.5	0.9	0.85	0.58
MCHC (%)	32.75 ± 0.71	32.55 ± 0.85	32.62 ± 1.14	32.94 ± 0.80	32.89 ± 0.71	32.91 ± 1.27	0.31	0.06	0.09	0.94	0.96	0.85
Platelet (×104/μL)	26.19 ± 4.55	25.83 ± 3.53	26.52 ± 6.01	26.21 ± 4.57	26.09 ± 3.96	25.68 ± 5.67	0.98	0.65	0.16	0.78	0.81	0.94
Ferritin (ng/mL)	83.01 ± 81.93	72.69 ± 85.31	83.99 ± 69.10	82.79 ± 80.38	70.59 ± 80.65	81.29 ± 65.35	0.93	0.63	0.51	0.96	0.69	0.67

Average ± standard deviation
Pre- and post-intervention comparison in P value, comparison among groups in P value
Pre- and post-intervention comparison analyzed with paired t-test, comparison among groups with ANOVA

apple raw without skin) [6]. There have been concerns that the effect of banana consumption on blood glucose, particularly the postprandial blood glucose spike, might be more pronounced than that of other foods; however, no studies have examined blood glucose spikes induced by banana consumption in Japanese populations.

The present study was conducted in three groups: group A (banana-at-breakfast group), in which 120 g of edible bananas was weighed and consumed raw at breakfast (at the beginning of breakfast as indicated) daily; group B (banana-at-dinner group), in which the same amount of bananas was also consumed raw at dinner (at the end of dinner as indicated); and group C (no banana group), in which no bananas or banana-containing foods were consumed.

Analysis of the primary endpoint, postprandial blood glucose spikes, showed that the incidence of blood glucose spikes was statistically significantly lower in the banana-at-breakfast group than in the banana-at-dinner and no banana groups. Steep and frequent postprandial blood glucose spikes should be avoided as much as possible for health reasons because they cause damage to the vascular endothelium and increase the risk of cardiovascular disease in the long term. In the present study, a "blood glucose spike" was defined as a blood glucose level >140 mg/dL at 30 min, 1 h, and 2 h after a meal, and the number of spikes, counted as the number of occurrences, was divided by the number of measurements to obtain the incidence ratio, which was calculated using the Poisson regression method.

Bananas are a sweet-tasting fruit; therefore, there is an impression that eating them raises blood glucose. However, the results of the present study indicate that eating bananas for breakfast may generate comparatively lesser blood glucose spikes, compared with eating bananas after dinner or not eating bananas at all.

Blood tests showed an increase in HbA1c levels after the intervention in the banana-at-dinner and no banana groups in pre- and post-intervention comparisons; however, the change was within the reference range. However, the effect recorded in the most recent 2 weeks, the study period, is not considered significant.

Furthermore, glycoalbumin level, an indicator of the average blood glucose level of approximately 2 weeks before blood sample collection, showed a statistically significant decrease

after the intervention in the banana-at-breakfast group in pre- and post-intervention comparisons. The possibility of an effect of the present intervention is conceivable.

For electrolytes, potassium levels increased after the intervention in the banana-at-breakfast group in pre- and post-intervention comparisons ($P<0.01$) and were higher in the banana-at- dinner and banana-at-breakfast groups in between-group comparisons; however, the increase was within the reference range and was unlikely to have been influenced by the intervention because potassium increases tend to occur with hemolysis during blood collection.

Chlorine, calcium, magnesium, and inorganic phosphorus levels showed changes in pre- and post-intervention comparisons; however, these changes were within the reference range, and the impact of the intervention is considered limited. The white blood cell count decreased in the no banana group, Hb levels decreased in the banana-at-dinner group, and hematocrit levels decreased in the banana-at-dinner group in pre- and post-intervention comparisons. However, all these changes were within the reference range and were unlikely to have been influenced by the present intervention. It is difficult to consider these changes to be due to the intervention. In addition, MCV decreased in the all three groups in pre- and post-intervention comparisons; however, the decrease was not due to this intervention.

This study has some limitations. First, the sample size was small (15-16 participants per group); therefore, the interpretation of the study's results cannot be generalized. In addition, the intervention period was short (<2 weeks); the frequency and timing of sustained blood glucose measurements were not uniform because they were conducted based on the participants' daily routines; and fluctuations in blood glucose were influenced by the combination of factors like foods, the order of food intake, and postprandial physical activity and exercise. This study was designed such that banana was to be consumed at the beginning of breakfast in the banana-at- breakfast group and at the end of dinner in the banana-at-dinner group; therefore, it did not compare the effect of banana intake per the timing within a meal, that is beginning of breakfast, during breakfast, and after breakfast. Furthermore, blood glucose at lunch was not measured. The interpretation of sustained blood glucose values was confounded by some factors, such as the lack of homogeneity in the blood glucose values.

However, to our knowledge, this is the first study to examine postprandial blood glucose in a Japanese population after eating bananas using a continuous glucose monitoring device and by obtaining data according to banana intake timing.

In conclusion, using a continuous glucose monitoring device, postprandial blood glucose fluctuations were examined in three groups (the banana-at-breakfast, banana-at-dinner, and no banana groups) in this study. The incidence ratio of blood glucose spikes was lower in the banana- at-breakfast group than in the banana-at-dinner or no banana group, when measured at dinner compared with at breakfast. In addition, glycoalbumin levels decreased significantly after the intervention in the banana-at-breakfast group. The present study compared the three groups, and the results suggest that the timing of banana consumption may affect blood glucose levels, and that consuming banana at the beginning of breakfast may be associated with a lower risk of cardiovascular diseases caused by postprandial glucose spikes, compared with consuming banana after dinner or not consuming banana at all.

Acknowledgments

Special thanks to all the volunteers who participated in this study.

Clinical Trial Registry Number

UMIN 000050025

Funding

The costs of the study and the provision of the test foods were borne by the Japan Banana Importers' Association.

Disclosure statements

Hiroyoshi Inoue has no conflicts of interest. Mitsuko Itoh, the principal investigator, has no conflicts of interest with the Japan Banana Importers' Association and was compensated for the study design, blood sampling, and data management of the study participants.

Data statements

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials

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