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Original article

The effect of *Yokan* and beverage intake on postprandial blood glucose levels

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Abstract

Glycative stress is a concept that refers to a state in which aldehydes, mainly derived from reducing sugars, lipids, and alcohol are excessively produced in the body, leading to aging and age-related diseases. Since the persistence of postprandial hyperglycemia contributes to increased glycative stress, understanding the impact of dietary carbohydrates on postprandial blood glucose levels is crucial for counting glycative stress. Many confectioneries, being very sweet and rich in sugar and lipids, are habitually consumed as snacks or desserts with beverages. This study examined the effects of *Yokan* (a type of Japanese confectionery) on blood glucose levels when ingested with a beverage, aiming to evaluate the impact of consuming Japanese confectionery on glycative stress.

The subjects were 21 healthy men and women aged 20-30 years who provided written consent to participate in the study. They did not meet any exclusion criteria and were selected based on selection criteria in a pre-test involving the ingestion of glucose water (reference food). The test foods included glucose water (test food A) as the reference, and *Yokan* with various beverages: water (B), green tea 1 (C), green tea 2 (D), guava leaf tea (E), and coffee (F). Each contained 50 g of carbohydrates, and the blood glucose level changes were monitored. The test was conducted using a FreeStyle Libre Pro, which measured the glucose concentration in the interstitial fluid of the skin tissue as an indicator of blood glucose level. Blood glucose levels were collected before consuming the test food multiple times over the next 120 minutes. The blood glucose change, maximum blood glucose concentration (ΔCmax), and incremental area under curve (iAUC) were measured and evaluated. The iAUC and ΔCmax after consuming the test foods B to F were lower compared to test food A. No differences in iAUC and ΔCmax were observed between the different beverages. The subjects were divided into three groups (H, M, L) based on the highest ΔCmax after consuming test food B, and differences in iAUC and ΔCmax after consuming the test foods were analyzed as a subclass analysis. In group H, the ΔCmax was smaller after consuming test food C compared to A, B, D, and E. The iAUC in group H was smaller after consuming test foods B, C, and F than A. Consuming *Yokan*, regardless of the type of beverage, resulted in a smaller increase in postprandial blood glucose levels compared to consuming glucose water. In group H, the suppression of blood glucose rise differed depending on the type of beverage consumed with *Yokan*, and beverages (C and F) had a strong effect on suppressing the rise in ΔCmax. Consuming *Yokan* with a beverage may be an effective method to reduce glycative stress caused by glucose spikes.

***KEY WORDS*:** postprandial blood glucose, *Yokan*, green tea, coffee, glycative stress

Introduction

In recent years, the concept of glycative stress [1)] has evolved from referring to the negative effects on the body caused by the production and accumulation of advanced glycation end products (AGEs) due to glycation to broader concepts that includes aging and disease caused by the excessive production of aldehydes (including ketones) mainly derived from reducing sugars, lipids, and alcohol in the body [2)]. Aldehydes in the body promote protein carbonylation and the production of AGEs, leading to protein browning and loss of elasticity. Glycative stress is a factor that accelerates

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skin aging, diabetic complications, osteoporosis, dementia, and other age-related degenerative diseases. Methods of reduce glycative stress, including suppressing hyperglycemic states, inhibiting glycation, and promoting the decomposition and excretion of AGEs [3,4]. Even in healthy people, sudden hyperglycemia after meals and excessive intake of lipids can increase aldehydes in the blood and thereby increase glycative stress [5,6]. For this reason, understanding the impact of dietary carbohydrates meals on postprandial blood glucose rise is important for countering glycative stress. Excessive intake of foods high in sugar is a factor in the progression of dental caries, obesity, and metabolic syndrome [7]. Sweets are often very sweet and rich in sugar and fat. They are mainly consumed as snacks or desserts. There is a common dietary habit of consuming snacks and desserts with beverages such as green tea, black tea, and coffee. These beverages contain various polyphenols. Many plant polyphenols inhibit carbohydrate-degrading enzymes, *i.e.*, amylase and α-glucosidase [8]. We have previously reported that when *Yokan* or sugar water with the same 50 g carbohydrate content is consumed, the rise in blood glucose level after consuming *Yokan* is smaller than that after consuming sugar water [9]. In this study, we aimed to evaluate the effect of consuming Japanese sweets on glycative stress by examining the impact on blood glucose levels after consuming *Yokan* with a beverage, assuming the dietary habit of consuming *Yokan* as a snack.

Methods

Subjects

Subjects were as follows: Men and women aged 18 to 30 years at the time of obtaining consent to participate in the study, healthy individuals with no chronic physical illnesses, individuals who have received a full explanation of the purpose and contents of the study, have the capacity to consent, and can voluntarily participate after fully understanding and giving written consent to participate in the study, and who are individuals who can come to the facility on the designated test date and take the test.

The following individuals were excluded: Individuals currently suffering from any disease and receiving drug treatment, individuals with a history or current illness of impaired glucose tolerance, mental illness, sleep disorder, hypertension, diabetes, hyperlipidemia, or other serious illnesses, individuals who have taken medication for the purpose of treating illness in the past month (excluding those who have taken medication for headaches, menstrual pain, colds, etc.), individuals with a history or current illness of serious disorders of the liver, kidneys, heart, lungs, blood, individuals with co-morbid or past diseases of the digestive organs (excluding those with a history of appendicitis), individuals with a body mass index (BMI) of 30 kg/m^2 or more, those who have donated more than 200 mL of blood in the past month, or more than 400 mL in the past three months, those with severe anemia, those who may develop allergic reactions to the test foods, or those who may develop severe allergic reactions to other foods or medicines, those who are pregnant, breastfeeding, or possibly pregnant, those who have continuously consumed functional foods or health foods that claim to be related to glucose metabolism within three months prior to the start of the study, or those who plan to consume such foods during the study period (intake for the purpose of maintaining health is acceptable), and those who are otherwise deemed unsuitable for this study by the principal investigator.

Survey items and test contents

The subjects filled out a survey form to determine their background, including their age, medical history, and whether or not they had any food allergies, and also underwent a blood test. The test was performed using a FreeStyle Libre Pro (Abbott Laboratories, Chicago, IL, USA), and the glucose concentration in the interstitial fluid of the skin tissue measured during the test period was used as the blood glucose level [10].

Study protocol

As with previous reports [11-15], this study was conducted with reference to the unified protocol [16] of the Japanese Glycemic Index (GI) Study Group. Subjects were instructed to observe the following during the study period.

Avoid irregular lifestyles such as lack of sleep and excessive eating and drinking, and lead a healthy life. Maintain the same quantity and quality of food, exercise, and sleep as before participating in this study. New intake of health foods or supplements is prohibited. Anything else that may affect the results of the study is prohibited. Subjects were instructed to observe the following on the day before and on the day of the study. Excessive exercise is prohibited on the day before the pre-examination and the test. Sleep at least six hours on the day before the test. Alcohol intake is prohibited from the day before the test until the end of the test on the day of the test. Avoid fatty foods for dinner on the day before the pre-examination and the test, and consume only water after 10 p.m. onwards. Exercise and physical activity that may cause sweating are prohibited on the day of the test until the end of the test. During the test, subjects were asked to sit and rest, and phone calls, sleep, excessive mental activity (email, computer, mobile phone), and physical activity were prohibited. After ingesting the test food, subjects were required to fast until the end of the test.

The subjects attached the Libre Pro sensor to the outer side of their upper arm by themselves at least two days before the test. There were no restrictions on bathing, swimming, or exercise, while wearing the Libre Pro sensor. Each test began at 10:00 and subjects ingested the test food for 10 minutes. After that, subjects watched a video in a sitting position, making sure to remain relaxed until the end of the test at 12:00.

The test food was chewed at least 30 times before swallowing. Blood glucose levels were collected before (first test), 15 minutes (second test), 30 minutes (third test), 45 minutes (fourth test), 60 minutes (fifth test), 90 minutes (sixth test), and 120 minutes (seventh test) after the start of ingestion of the test food.

Test Foods

The nutritional content of the test foods used in this study was calculated using the values displayed on each food, and the carbohydrate intake per meal was standardized to 50 g (***Table 1***). In this study, commercially available *yokan* products, mineral water, carbonated water, green tea leaves, two types of beverages, coffee beans, and glucose were used. Glucose water was prepared by dissolving 54.8 g of glucose (product name: Glucose, Margo Corporation, Saitama, Japan) in mineral water (product name: I・Ro・Ha・Su Natural Water, Asahi Soft Drinks, Tokyo, Japan), and then adding a small amount of carbonated water (product name: Wilkinson Carbonated Water, Asahi Soft Drinks, Tokyo) to make 200 mL. *Yokan* products (product name: Yoru no Ume, Toraya, Tokyo) were used. Green tea 1 was obtained by extracting 15 g of tea leaves (product name: Kyo no Fumi, Toraya) in 270 mL of hot water at 60～70 °C for two minutes. Green tea 2 (product name: Oi Ocha, Itoen, Tokyo) and guava leaf tea (product name: Bansouricha, Yakult Honsha, Tokyo) were commercially available bottled beverages. Coffee was obtained by steaming 17 g of ground bean powder (product name: Organic Regular Coffee, Key Coffee, Tokyo) for 20 seconds in a small amount of boiling water using the paper drip method, and then extracting with a total volume of 200 mL. The test foods were A to F, and the intake amounts were as follows:

A (reference food):
200 mL glucose water (carbohydrates: 50 g)
B (test food):
71 g *Yokan* + 200 mL water (total carbohydrates: 50 g)
C (test food):
71 g *Yokan* + 200 mL green tea (1)
(total carbohydrates: 50 g)
D (test food):
71 g *Yokan* + 200 mL green tea (2)
(total carbohydrates: 50 g)
E (test food):
71 g *Yokan* + 200 mL guava leaf tea
(total carbohydrates: 50 g)
F (test food):
71 g *Yokan* + 200 mL coffee (total carbohydrates: 50 g)

All test foods A to F were consumed within 10 minutes of the start of the test.

Selection of subjects for safety analysis (intention to treat: ITT)

The ITT was comprised of subjects who had consumed the test food at least once.

Selection of subjects for efficacy analysis (per protocol set: PPS)

The PPS was comprised of the ITT enrolled in the study who had completed all of the prescribed test schedule and content (full analysis set: FAS). Individuals who exhibited significant behavior that undermined the reliability of the test results, or who met the exclusion criteria or were found to be unable to comply with the restrictions after starting intake were excluded.

Statistical analysis

The safety evaluation and analysis of the study were performed using ITT, and the symptoms, severity, and frequency of adverse events and side effects were evaluated. The efficacy analysis of the results was performed using PPS, and the blood glucose change value (Δ blood glucose; ΔBG) was calculated by subtracting the blood glucose value before taking the test food (first time: 0 min) from the blood glucose value over time after taking the test food, and the maximum blood glucose change value (ΔCmax; maximum blood glucose concentration) was calculated by the maximum blood glucose change value up to 120 min after the start of the test. The area under the blood glucose rise curve (incremental area under curve; iAUC) was calculated according to the unified protocol of the Japan Glycemic Index (GI) Study Group [16]. Statistical analysis was performed using the statistical analysis software BellCurve for Excel (Social Information Service, Tokyo). The blood glucose value was expressed as the mean ± standard error (SE), and ΔCmax and iAUC were expressed as the mean ± standard deviation (SD). Between-group comparison of test results was performed using the Bonferroni multiple testing method, with a two-sided test of less than

Table 1. Nutrition fact of test food.

Test food	Serving unit (g)	Beverage (mL)	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Sodium chloride (g)
A	54.8	200	184	0	0	50	0
B	71	200	211	2.9	0	50	0
C	71	200	213	3.2	0	50	0
D	71	200	211	2.9	0	50	0
E	71	200	214	3.2	0	50	0
F	71	200	211	2.9	0	50	0

A, Dissolved glucose in water; B, Yokan with water; C, Yokan with green tea (1); D, Yokan with green tea (2); E, Yokan with Guava leaf tea: F, Yokan with coffee. Details of the test food are shown in body text.

5 % ($p < 0.05$) considered significant, and $0.05 \leqq p < 0.1$ considered to indicate a significant trend.

Ethical standards

This study was conducted in compliance with the Declaration of Helsinki (amended at the WMA General Assembly in Fortaleza in 2013) and the ethical guidelines for medical research involving human subjects (notification of the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare). The content of the study was fully explained to the subjects in advance, and the subjects were required to participate in the study and submit a voluntary consent form. This study was conducted under the deliberation and approval of the Ethics Committee for "Research involving Human Subjects" of the Glycative Stress Research Group (approval number: GSR 2023-002). This study was also registered in the public database established by the National University Hospital Directors' Conference (UMIN) (study ID: UMIN000052744).

Results

Safety evaluation

No adverse events were reported in this study (data not shown).

Selection of subjects for efficacy analysis

Twenty-one subjects wished to participate in this study. Of these, three withdrew from participation due to personal reasons before the pre-test. Subsequently, the ITT for this study was 18 subjects. The ITT did not meet the exclusion criteria, and none of the subjects had a pre-test result with the Japan Society of Health Checkups classification D (requiring detailed examination/treatment) or abnormal values in the LSI Medience (Tokyo) test results, and all were healthy adults.

In the ITT reference diet (test diet A) intake test, three subjects (subjects with iAUC less than 3,000 mg/dL* min and ΔCmax less than 70 mg/dL) who did not meet the selection criteria (those with high iAUC and ΔCmax) were excluded from the subsequent test subjects for intake of test diets B to F. Subsequently, the total number of FAS was 15 (11 women and four men) (***Table 2, 3***). Differences or trends of differences between men and women were observed in height, weight, body fat percentage, systolic blood pressure, AST, ALT, creatinine, uric acid, red blood cell count, hemoglobin, and hematocrit. However, these differences were unlikely to affect the analysis of the results of this study. For this reason, all FAS participants were analyzed as PPS in the subsequent analyses.

Analysis of efficacy

1. Total analysis

The changes in blood glucose levels from the start of ingestion of test foods A to F until 120 minutes later are shown (***Table 4, Fig. 1***). Fasting blood glucose levels before the start of the test food A were 89.7 ± 1.8 mg/dL (mean ± 95 % CI [confidence interval], n = 90). No difference in fasting blood glucose levels was observed between the test foods. Therefore, it was assumed that the blood glucose state of the subjects at each consumption test was the same. Blood glucose levels after consuming of the test foods reached their highest value 45 minutes after consumption and then decreased. Differences in ΔBG between the test foods were observed from 15 minutes after the start of the test, and after 30 minutes, test food C had a lower value than B and E ($p < 0.05$), and tended to be lower than D ($p < 0.1$). 120 minutes after the start of the test, B, E, and F ($p < 0.05$) had lower values than test food C. The iAUC and ΔCmax were lower for B – F compared to the reference (test food A) ($p < 0.05$, ***Fig. 2***). However, no differences in iAUC and ΔCmax were observed due to the differences in beverages (B – F).

2. Subclass analysis

Subjects were divided into three groups (H group: top 5, M group: middle 5, L group: bottom 5) based on the highest ΔCmax results when taking test food B (*Yokan* + water), and the differences in iAUC and ΔCmax after taking the test food were examined as subclass analysis. The ΔCmax of the subclass groups when taking test food B was H group (69.4 ± 14.1 mg/dL, n = 5), M group (52.4 ± 5.0 mg/dL, n = 5), and L group (39.6 ± 4.9 mg/dL, n = 5), and the H group was 1.8 times higher than the L group ($p < 0.05$). Both the ΔCmax and iAUC of each group when taking the reference (test food A: glucose water) were higher in the H group than in the L group ($p < 0.05$) (***Fig. 3***). The ΔCmax of Group H was smaller when taking test food C than when taking test foods,

Table 2. Subjects profile.

Item	Unit	Total	Female	Male
Number of subjects	–	15	11	4
Age	years	22.4 ± 1.0	22.3 ± 1.1	22.8 ± 0.8
Body height	cm	159.8 ± 6.9	156.4 ± 4.3	169.2 ± 2.7
Body weight	kg	49.9 ± 6.9	47.1 ± 5.3	57.7 ± 4.4
Body fat	%	24.0 ± 5.9	25.8 ± 5.4	19.2 ± 4.1
BMI	–	19.4 ± 2.6	19.1 ± 2.8	20.1 ± 1.6

Results are expressed as mean ± standard deviation. BMI, body mass index.

Table 3. Results of blood chemistry test.

Test item	Unit	Measured value (mean ± SD)	Reference range
FBG	mg / dL	82.7 ± 6.6	≦ 99
HbA1c	%	5.2 ± 0.2	≦ 5.5
IRI	μU / mL	5.4 ± 3.3	–
Total cholesterol	mg / dL	169.8 ± 16.9	–
HDL-C	mg / dL	72.6 ± 12.5	40 – 119
LDL-C	mg / dL	83.6 ± 15.0	60 – 119
TG	mg / dL	67.7 ± 43.8	30 – 149
AST	U / L	20.4 ± 9.5	≦ 30
ALT	U / L	13.6 ± 5.9	≦ 30
γ-GT	U / L	14.0 ± 3.6	≦ 50

Results are expressed as mean ± standard deviation, n = 15, FBG, fasting blood glucose; IRI, immunoreactive insulin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglyceride; AST, aspartate transaminase; ALT, alanine transaminase; γ-GT, γ-glutamyltransferase.

Table 4. Blood glucose level fluctuation after a test food intake.

Test food	Time (min)						
	0	15	30	45	60	90	120
A	87.4 ± 6.1	111.5 ± 10.7	150.1 ± 11.4	164.1 ± 10.5	151.8 ± 12.9	123.3 ± 10.8	108.8 ± 10.7
B	92.1 ± 3.9	111.5 ± 6.4	139.0 ± 7.2	139.1 ± 10.3	121.7 ± 13.0	98.7 ± 8.7	92.9 ± 5.9
C	87.7 ± 4.4	101.3 ± 6.1	122.3 ± 7.2	130.5 ± 5.9	122.8 ± 8.2	103.7 ± 7.8	102.5 ± 8.5
D	91.1 ± 3.3	108.1 ± 5.9	137.1 ± 4.4	143.6 ± 7.1	128.9 ± 9.7	100.3 ± 8.1	97.6 ± 5.7
E	90.0 ± 3.7	107.5 ± 5.9	131.3 ± 7.2	135.8 ± 7.9	124.7 ± 10.1	103.3 ± 7.4	92.5 ± 5.6
F	89.7 ± 3.6	109.8 ± 6.4	137.5 ± 7.1	141.5 ± 9.2	123.9 ± 11.1	101.5 ± 6.4	92.4 ± 4.8

Unit; mg/dL, Results are expressed as mean ± 95 % CI, n = 15, A-F; details of the test food are shown in **Table 1**. CI, confidence interval.

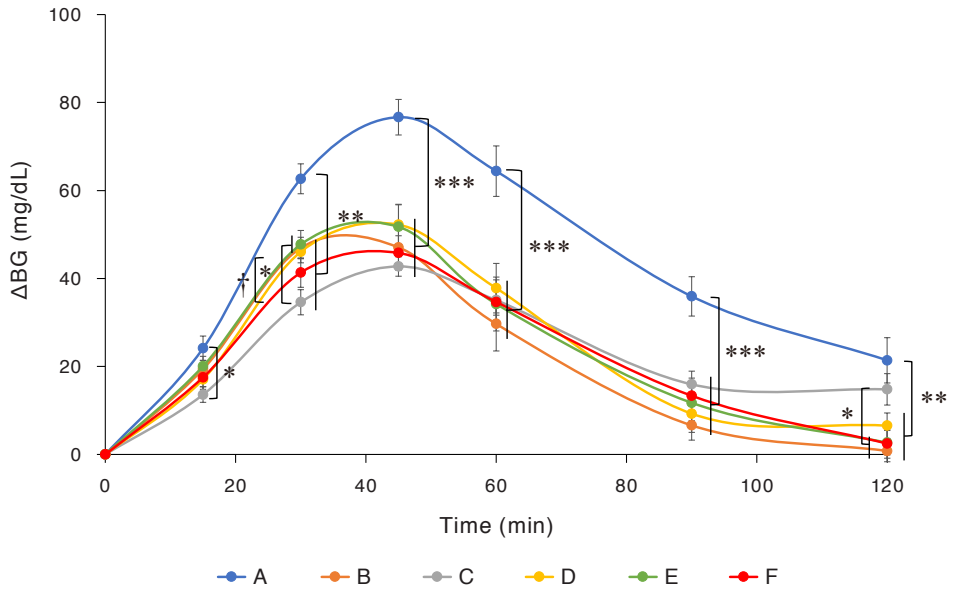

Fig. 1. **Fluctuation of the ΔBG level at the time of test food intake.**

Results are expressed as mean ± standard error, n = 15, † $p < 0.1$, * $p < 0.05$, Bonferroni test. A-F; details of the test food are shown in **Table 1**. ΔBG, blood glucose change value.

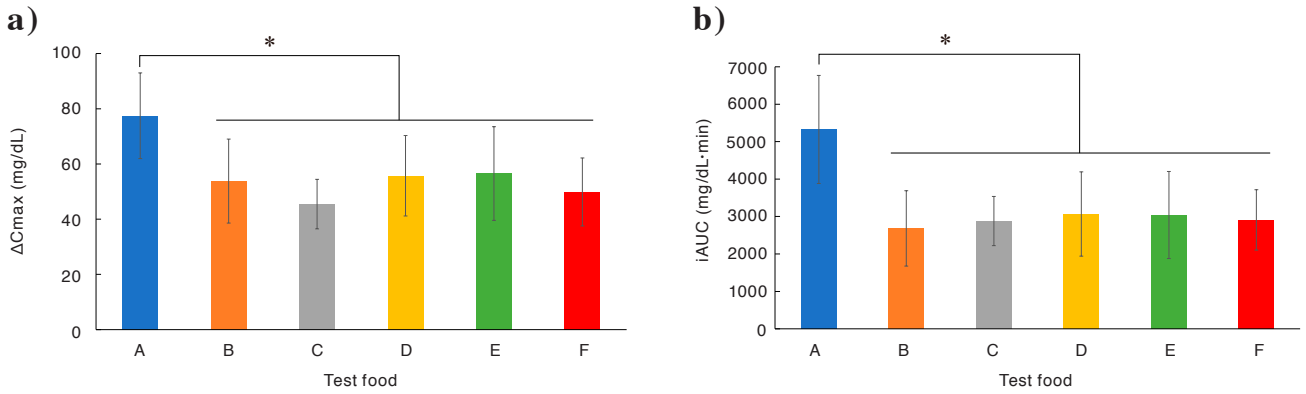

Fig.2. **The amount of ΔCmax and iAUC after test food intake.**

a) ΔCmax, **b)** iAUC, Results are expressed as mean ± standard error, n = 15. † $p < 0.1$, * $p < 0.05$, Bonferroni test. A-F; details of the test food are shown in **Table 1**. ΔCmax, maximum blood glucose level change; iAUC, incremental area under the curve of blood glucose level change.

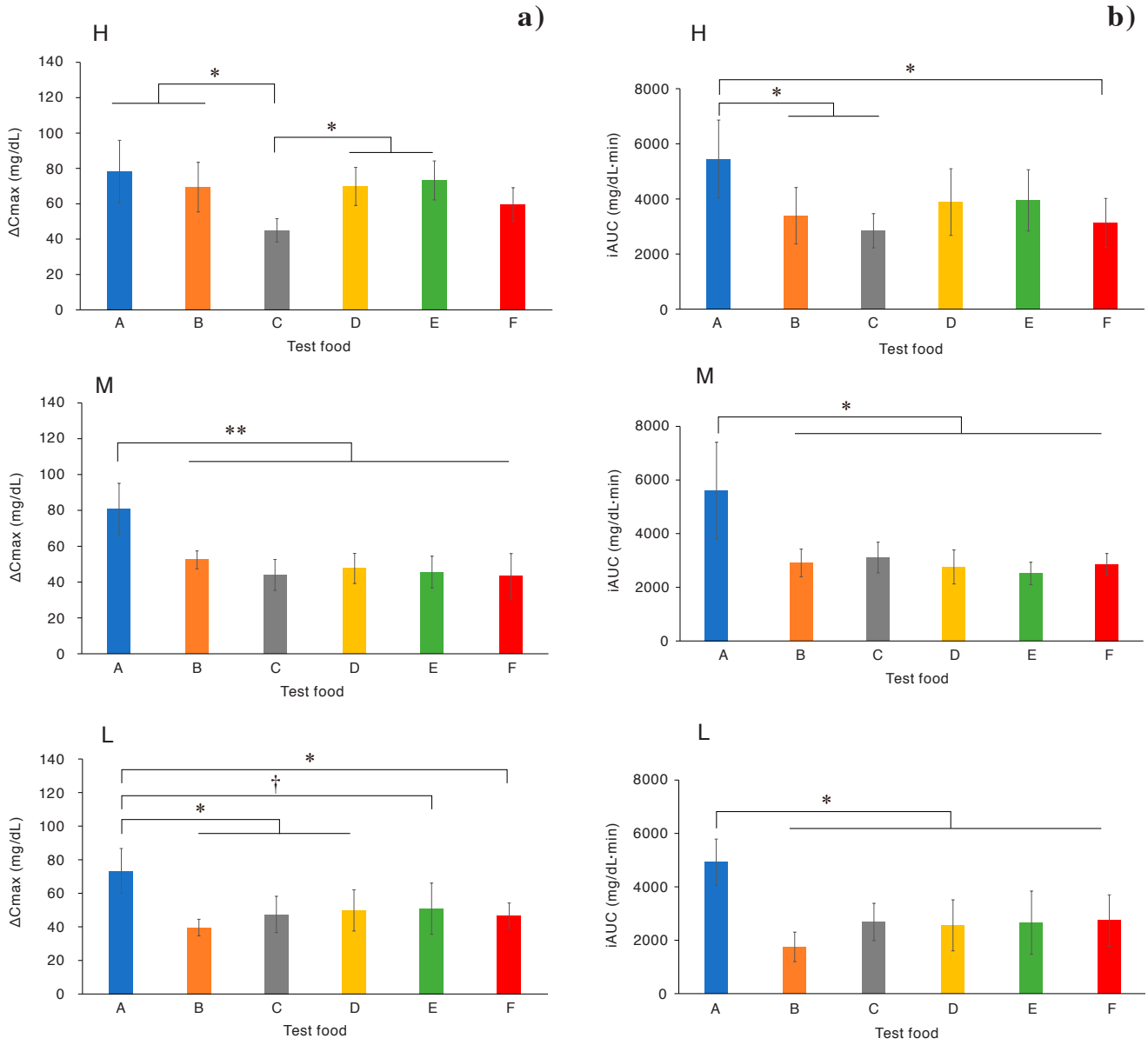

Fig.3. **Subclass analysis of ΔCmax and iAUC after test food intake.**

a) ΔCmax, **b)** iAUC, Results are expressed as mean ± standard error, n = 5, † $p < 0.1$, * $p < 0.05$, Bonferroni test, A-F; details of the test food are shown in **Table 1**. ΔCmax, maximum blood glucose level change; iAUC, incremental area under the curve of blood glucose level change. H; higher group (n = 5), M; middle group (n = 5), L; lower group (n = 5).

A, B, D, and E ($p < 0.05$). The iAUC of Group H was smaller when taking test foods B, C, and F than when taking A. The middle group had smaller ΔCmax and iAUC regardless of the type of beverages (B-F) taken with the *Yokan* compared to when taking A ($p < 0.05$). The low group had smaller iAUC for beverages B-F taken with the *Yokan* compared to when taking A ($p < 0.05$). The ΔCmax of the low group was smaller when taking B-D and F compared to when taking A ($p < 0.05$), and tended to be lower when taking E ($p < 0.1$).

Discussion

Effect of beverages consumed with Yokan on postprandial blood glucose levels

To suppress postprandial hyperglycemia, there are several methods, including reducing carbohydrate intake, choosing low glycemic index (GI) foods that cause a gradual rise in postprandial blood glucose levels[17], eating foods high in protein, lipids, acetic acid, and dietary fiber along with carbohydrates[18], and eating vegetables before carbohydrates[15]. In a previous report, subjects consumed *Yokan*, rice, and sugar water each with the same 50 g of carbohydrates, it was found that *Yokan* had lower iAUC and ΔCmax than sugar water, and lower iAUC than rice[9]. In this study, we examined the effect on blood glucose levels after consuming *Yokan* with five types of beverages (B to F). As a result, ΔCmax and iAUC were lower for *Yokan* and beverages compared to glucose water (test food A). Furthermore, a subclass analysis was conducted by dividing the subjects into thirds according to the highest ΔCmax of *yokan* and water (test food B). The ΔCmax in group H was lower for *yokan* and green tea 1 (C) than for A, *yokan* and water (B), *yokan* and green tea 2 (D), and *yokan* and guava leaf tea (E). Concurrently, the iAUC was lower for B, C, and *yokan* and coffee (F) than for A. These results indicate that the rise in blood glucose level after ingesting *yokan*, a sweet food containing sugar, is smaller than that of sugar water, and that the beverage consumed with *yokan* has the effect of suppressing the rise in blood glucose level.

Green tea mainly contains four types of catechins (EGCG: epigallocatechin gallate, EGC: epigallocatechin, ECG: epicatechin gallate, EC: epicatechin)[19]. Of the beverages used in this study, test foods C and D were green tea. The degree of processing and oxidation of tea varies depending on the type, and the concentration of catechins varies depending on the extraction method[20]. Tea with a high content of EGCG and EGC has a large α-glucosidase inhibitory effect, which is stronger than that of acarbose[19]. The difference in α-glucosidase inhibitory effect between the two types of green tea (C and D) was thought to be due to the processing method of the tea leaves and the type and content of catechins associated with it. Guava leaf tea has been commercialized as a food for specified health uses, as it reduced postprandial blood glucose levels in subjects aged 40 years or older and with a BMI of 22.0 or higher who consumed rice[21]. Hot water extracts of guava leaves have been found to have α-amylase and glucosidase inhibitory effects, and guava leaf polyphenols have been identified as the active ingredients[22]. It was assumed that the difference between test foods E and C and D was due to the difference in the type and content of polyphenols in the test foods.

The coffee in test food F contains chlorogenic acid[23]. Chlorogenic acid has been reported to have an α-glucosidase inhibitory effect[24]. Therefore, it was estimated that the rise in blood glucose level after ingestion of the test food was due to the α-glucosidase inhibitory effect of various polyphenols in the beverage consumed with the *yokan*. The difference between the results of the following overall analysis and subclass analysis was estimated to be due to the influence of the subjects' susceptibility to postprandial blood glucose levels. The ΔCmax of the subclass group after ingestion of test food B was 1.8 times higher in group H than in group L ($p < 0.05$), but no difference was observed in fasting blood glucose levels (before ingestion of the test food). The suppression of blood glucose increased after ingesting bread containing heat-moisture-treated high-amylose corn starch (HMT-HSA), and was more pronounced in company workers (mean age: 36.9 ± 9.3 years, n = 19) than in university students (22.6 ± 1.3 years, n = 13). The cause of this is thought to be the progression of insulin resistance associated with aging in the subjects[25]. Young people who show postprandial hyperglycemia may have a stronger suppression effect of ingested foods on blood glucose rise, just like middle-aged and elderly people.

GI value when yokan and beverage are consumed at the same time

One of the indicators that shows the level of rise in blood glucose level for each food is the glycemic index (GI)[17]. In this study, the iAUC (n = 15) of test food A (glucose water) was set at 100, and the GI was calculated as follows: B: 50.4, C: 54.1, D: 57.6, E: 57.0, and F: 54.6. When glucose is used as the standard food, the GI of each test food is considered to be high GI foods with a value of 70 or more, medium GI foods with a value of 69 to 56, and low GI foods with a value of 55 or less[26]. From the GI perspective, test foods B, C, and F were low GI foods, and D and E were medium GI foods. Buckwheat, pasta, udon, and vermicelli are known to be low and medium GI foods[27]. *Yokan* was considered to be a food that has little effect on postprandial blood glucose levels if consumed in moderation and with a beverage.

Suppression of dietary glycative stress

The goal of suppressing dietary glycative stress is to prevent postprandial hyperglycemia and the accumulation of AGEs in the body. *Yokan* is a sweet food that contains a lot of sugar, so it is a food that requires caution regarding the rise in blood glucose levels. In the subclass analysis of this study, the rise in postprandial blood glucose levels was reduced when it was consumed together with beverages containing α-glucosidase inhibitors, such as green tea and coffee. The effect of sweet foods on glycative stress is important in terms of the amount consumed and the type of beverage consumed together. *Yokan* is not a staple food, but a food that can be eaten as a snack or dessert. The consuming sweets as a snack improves attention function and memory[28,29]. It has also been reported that sweets can lead to more active communication and improved creativity in group life[30]. In recent years, it has been reported that when simple carbohydrates (monosaccharides and disaccharides) are consumed in response to appetite,

FGF21 (fibroblast growth factor [21]) is secreted from the liver, which activates oxytocin neurons and activates oxytocin receptor-positive neurons in the brain, suppressing the appetite for sugar [31, 32]. Intake of sweet foods containing sugar can have a positive effect if consumed in appropriate amounts. One way to set sugar intake is to use food exchange lists [33]. The traditional Japanese dietary habit of combining *yokan* with beverages may be a way to counter glycative stress and enrich life.

Study limitationsn

The subjects in this study were 22.4 ± 1.0 years old and showed no decline in glucose metabolism. Glucose metabolism declines with age. Therefore, the effects on middle-aged and elderly subjects and subjects with reduced glucose metabolism need to be verified separately. However, since the subclass analysis showed differences in ΔCmax depending on the beverage consumed by subjects with high ΔCmax after ingesting test meal B, beverages consumed by middle-aged and elderly people with *Yokan* may have a similar effect to the results of this study.

Conclusion

It was shown that the risk of postprandial blood glucose rise is smaller when *Yokan* is consumed, regardless of the type of beverage consumed, compared to glucose water (reference meal). In subjects with high ΔCmax after ingesting *Yokan*, the type of beverage had a different effect of suppressing blood glucose rise, and it was possible that beverages consumed with *Yokan* (green tea 1, coffee) had a strong effect of suppressing the rise in ΔCmax. A diet that involves ingesting both *Yokan* and beverages may lead to a reduction in glycative stress caused by blood glucose spikes.

Conflict of interest declaration

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