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Effect of Intake Order of Rice, Meat, and Vegetables on Postprandial Blood Glucose Level in Healthy Young Individuals

Tatsuhiro Matsuo, Shunsuke Higaki[1] and Reiko Inai[2]

Abstract

In Japan, type 2 diabetes mellitus is listed a major health concern that requires serious attention. Postprandial elevation of blood glucose levels is an early sign of the development of diabetes. In recent years, dietary methods such as vegetable-first or meat-first diets, where vegetables or meat is consumed before carbohydrate sources such as rice, have been attracting attention to suppress the increase in blood glucose levels after meals. In this study, we investigated the effect of the intake order of rice, meat, and vegetables on the increase in postprandial blood glucose levels in young healthy participants. We also compared the effects of triangular eating, a traditional Japanese diet, on postprandial blood glucose levels. Participants ingested a test meal consisting of three separate dishes of rice, vegetables, and meat in different orders on 7 different days. Subsequent changes in blood glucose levels were measured over 120 min. We demonstrated that eating meat before rice (meat-first diet) reduced postprandial glucose elevation compared with the reverse regimen. However, the advantages of eating vegetables before rice (vegetable-first diet) could not be confirmed. In addition, effects of triangular eating on postprandial glucose elevations were comparable to those of the meat-first diet. The meat-first diet or triangular eating may be a safe and effective dietary therapy to prevent diabetes.

Key words : intake order, rice, meat, vegetables, blood glucose

Introduction

In Japan, type 2 diabetes mellitus is listed as a major health concerns that require serious attention. The increasing number of patients with diabetes in Japan over the past few decades has been regarded as a fundamental problem and extensively discussed[(1)]. Postprandial elevation of blood glucose levels is an early sign of diabetes development[(2)] and these levels are more strongly associated with glycated hemoglobin (HbA1c) levels, especially in Japanese patients with type 2 diabetes[(3)]. In addition, postprandial blood glucose levels are recognized as independent risk factors for cardiovascular disease[(2, 3)]. Therefore, controlling these levels may be a therapeutic target for the prevention of diabetes and cardiovascular disease[(4)]. However, it is difficult to control postprandial blood glucose levels with a balanced nutritional diet alone, and various diets have been considered to offer appropriate control.

In recent years, dietary methods such as vegetable-first or meat-first diets have attracted attention in suppressing an increased postprandial blood glucose levels. In these diets, individuals eat vegetables or meat dishes before consuming boiled rice, a major Japanese staple that is composed of mostly complex carbohydrates[(5, 6)]. The vegetable-first diet involves eating vegetables before staple foods. The dietary fiber contained in vegetables suppresses the rise in blood glucose levels after meals by delaying glucose absorption[(5, 6)]. The meat-first diet involves eating the main dish, such as those containing meat, before staple foods. The proteins and lipids in the meat deshes promote the secretion of glucagon-like peptide-1 (GLP-1) and glucose-dependent insulinotropic polypeptide (GIP), gastrointestinal hormones that stimulate insulin secretion. This, in turn, suppresses the increase in blood glucose levels after meals[(7, 8)]. However, few studies have comprehensively examined the effects of the intake order of rice (staple food), meat (main dish), and vegetables (side dish) on postprandial blood glucose levels.

[1] Faculty of Human Sciences, Hokkaido Bunkyo University, 5-196-1 Koganechuo, Eniwa Hokkaido 061-1449, Japan
[2] Department of Food Science and Nutrition, Nara Women's University, Kitauoyanishimachi, Nara, Nara 630-8263, Japan

Moreover, the traditional Japanese triangular eating (TE) method, in which staple foods, main dishes, and side dishes are eaten alternately bit by bit, has long been established[9]. This eating method also called “oral seasoning” is a dietary method in which a variety of ingredients are mixed in the mouth to enjoy the changing flavors. With this method, the number of chews naturally increases, and saliva secretion is promoted [9]. However, the effect of TE on the rise in blood glucose levels after meals remains unclear.

In this study, we comprehensively investigated the effects of the intake order of boiled rice (staple food), meat (main dish), and vegetables (side dish) on the increase in postprandial blood glucose levels. We also compared the effects of TE on postprandial blood glucose levels.

Materials and Methods

Participants

Six healthy individuals (three males and three females) who had no family history of diabetes and were not currently on medication participated in this study. The physical characteristics of the participants are presented in Table 1.

Table 1　Physical characteristics of participants

No.	Sex	Age	Height (cm)	Weight (kg)	BMI*
1	Male	21	173	57	19.1
2	Male	22	171	59	20.2
3	Male	21	170	56	19.4
4	Female	21	158	53	21.2
5	Female	21	153	51	21.8
6	Female	22	155	55	22.9

*Body mass index: Weight (kg) / Height (m)^2

Test meal

The test meal consisted of three types of dishes: staple food (rice, R), main dish (meat, M), and side dish (vegetables, V). The composition of the test meal is presented in Table 2. The staple food consisted of 180 g of commercially available packed boiled rice (TableMark Co., Ltd., Tokyo, Japan). The main dish consisted of 120 g of retort-packed humburg steak, composed of a mixture of minced beef and pork (Prima Meat Packers, Ltd., Tokyo, Japan). The side dish was green salad comprising 50 g lettuce, 30 g cucumber, 40 g tomato, and 15 g non-oil dressing (Kewpie Corporation, Tokyo, Japan). The number of calories in each meal was 520 kcal, with a nutrient-energy ratio of 14.9% protein, 24.1% fat, and 61.0% carbohydrate. The test meal contained 4.0 g of dietary fiber.

The test meals were prepared by a dietitian. The order of intake of the test meals is shown in Fig. 1 and was as follows: MVR: meat, vegetables, and rice; MRV: meat, rice, and vegetables; VMR: vegetables, meat, and rice; VRM: vegetables, rice, and meat; RMV: rice, meat, and vegetables; RVM: rice, vegetables, and meat. Regarding TE, the participants were randomly and alternately allowed to eat meat, vegetables, and rice in small amounts. Participants drank 200 ml of water with a test meal and finished eating within 15 min. The participants received seven different meals (TE, MVR, MRV, VMR, VRM, RVM, and RMV) on seven different days, with a 3-day washout period between the test meals.

Experimental procedures

Participants visited the laboratory at 9:00 on seven different days after having fasted overnight. The meal on the day before the examination was taken as a normal meal, and food intake other than water was forbidden from 21:00. Peripheral blood was drawn from the fingertips for blood glucose measurement and were measured using a glucose analyzer (GT-1820;

Table 2　Composition of a test meal

	Weight (g)	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Fiber (g)
Rice: Boiled rice	180.0	261.0	4.5	0.5	59.6	2.7
Meat: Hamburg steak	120.0	232.5	13.5	13.1	15.3	n.e.
Vegetables: Green salad						
Lettuce	50.0	6.0	0.3	0.05	1.4	0.6
Cucumber	30.0	4.2	0.3	0.03	0.9	0.3
Tomato	40.0	7.6	0.3	0.04	1.9	0.4
Dressing	15.0	9.0	0.6	0.3	0.7	0.0
Total	438.0	520.3	19.5	14.0	79.8	4.0
Energy ratio (%)			14.9	24.1	61.0	

n.e.: Not evaluated.

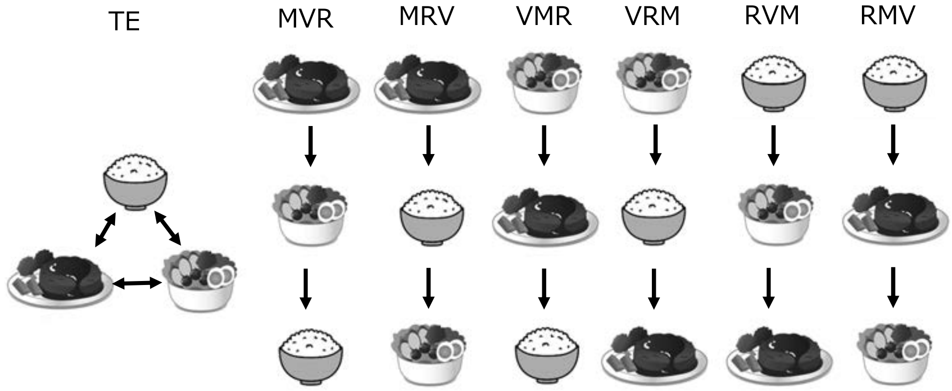

Fig. 1 Study protocol for dietary eating orders. TE: triangular eating. The order of intake of different test meals is as follows: MVR: meat, vegetables, and rice; MRV: meat, rice, and vegetables; VMR: vegetables, meat, and rice; VRM: vegetables, rice, and meat; RMV: rice, meat, and vegetables; RVM: rice, vegetables, and meat.

Arkray, Inc., Kyoto, Japan).

Following blood collection, participants consumed one of the seven test meals, and the start of the test meal intake was considered 0 min. Blood was then collected again at 30, 60, 90, and 120 min to measure glucose levels. The area under the blood glucose concentration-time curve (AUC) between 0 and 120 min was calculated using the trapezoidal rule.

Data analysis

Dunnett's test was used to compare group TE with the other six groups. Data from the six groups, aside from the group TE, were analyzed using two-way analysis of variance (ANOVA) and the Tukey-Kramer test. The intake order of meat and rice (M-R) and the timing of vegetable consumption (V) were factors in the ANOVA. Statistical significance was set at $p < 0.05$. Excel Statistics (Social Survey Research Information Co. Ltd., Tokyo, Japan) was used for data analysis.

Results and Discussion

The results of the ANOVA are shown in Table 3, and the blood glucose concentrations and AUC after intake of test meals are shown in Table 4. Based on the ANOVA results, eating meat before rice significantly reduced blood glucose concentrations at all sampling times, except for the 120-min value and AUC (Table 3). In contrast, the timing of eating vegetables had no effect at most sampling times except for the 90-min value (Table 3). No synergistic effect was observed between eating meat before rice as well as the timing of eating vegetables on blood glucose levels and AUC (Table 3). At 0 and 30 min after meals, blood glucose levels did not differ among the test meals (Table 4). At 60 min after meals, blood glucose levels were significantly lower in meal MVR than in meals VRM and RVM and were lower in meal TE than in meals VRM and RVM (Table 4). At 90 min after meals, blood glucose levels were significantly lower in meal MVR than in meal RMV and were lower in meal TE than in meal RVM (Table 4). At 120 min after meals, blood glucose levels did not differ among the six meals, but did with meal TE, in which they were lower than meal VMR. The AUC was significantly lower in meal MVR than in meals VMR, VRM, RVM, and RMV, and was significantly lower in meal TE than in meals VRM, RVM, and RMV (Table 4). The AUC was lower in order of MVR, TE, MRV, VMR, VRM, RVM, and RMV (Table 4).

In the present study, we comprehensively investigated the effect of intake order of rice, meat, and vegetables as well as TE on postprandial blood glucose in young healthy participants. We found that the meat-first diet suppressed postprandial blood glucose elevations. Various studies have investigated the effects of ameliorating postprandial blood glucose levels by ingesting proteins and amino acids before carbohydrate in-

Table 3 Results of two-way analysis of variance

Time (min)	M-R[2]	V[3]	M-R × V
0	$p<0.05$	n.s.	n.s.
30	$p<0.01$	n.s.	n.s.
60	$p<0.05$	n.s.	n.s.
90	$p<0.05$	$p<0.05$	n.s.
120	n.s.	n.s.	n.s.
AUC[1]	$p<0.001$	n.s.	n.s.

n.s. : No significant difference. [1]Area under the curve.
[2]Intake order of meat and rice. [3]Timing of eating vegetables.

Table 4 Blood glucose concentrations and AUC[1] after intake of test meals

Means	Blood glucose (mg/dl)						
Time (min)	TE[2]	MVR	MRV	VMR	VRM	RVM	RMV
0	81 ± 7	87 ± 9	85 ± 10	85 ± 9	93 ± 6	90 ± 8	92 ± 4
30	131 ± 8	121 ± 12	124 ± 8	129 ± 10	138 ± 14	142 ± 17	139 ± 11
60	113 ± 13	109 ± 14[b]	129 ± 21[ab]	129 ± 17[ab]	139 ± 8[*a]	139 ± 9[*a]	131 ± 16[ab]
90	106 ± 7	94 ± 8[b]	110 ± 13[ab]	114 ± 10[ab]	112 ± 10[ab]	113 ± 16[ab]	127 ± 11[*a]
120	96 ± 9	105 ± 8	112 ± 15	122 ± 14*	116 ± 13	110 ± 13	117 ± 15
AUC (mg/dl · min)	13138 ± 800	12570 ± 640[b]	13835 ± 911[ab]	14265 ± 782[a]	14760 ± 577[*a]	14805 ± 891[*a]	15028 ± 1044[*a]

Values are the mean ± SE for 6 subjects. [1]Area under the curve. [2]Triangular eating. *$p < 0.05$ vs. TE (Dunnett test).
Within a row, superscripts indicate statistical differences between values ($p < 0.05$) (Two-way ANOVA and Tukey-Kramer test).

take[5, 8, 10-12]. For instance, Ma, et al.[12] reported that the intake of 55 g of whey protein before a carbohydrate dish enhanced GLP-1 and ameliorated postprandial glucose elevation. Moreover, Samocha-Bonet, et al.[13] demonstrated that intake of 40 g glutamine before a mixed meal enhanced GLP-1 and insulin secretion and ameliorated postprandial glucose elevation. Several studies have also investigated the effects of the pre-intake of fats[14]. GLP-1 is one of two incretins secreted from the gut in response to the ingestion of proteins and fats, and it stimulates insulin secretion from pancreatic β-cells in a glucose-dependent manner[15]. In addition, GLP-1 suppresses glucagon secretion from pancreatic α-cells and delays gastric emptying, thereby ameliorating postprandial glucose elevation[15]. In this study, the meat dishes (hamburger steak) contained 13.5 g of protein and 13.1 g of fat, which may have suppressed the rise in postprandial blood glucose levels by promoting the secretion of GLP-1.

However, knowledge of the effects of the timing of vegetable consumption is limited. The suppressive effects of vegetables on blood glucose elevation may be due to the dietary fibers contained therein, and the effects of the pre-intake of dietary fibers have been intensively discussed. Dietary fiber, a generic term for components that are not digested and absorbed in the small intestine, has been shown to prevent diabetes and obesity by suppressing the absorption of carbohydrates and fats[16]. In addition, dietary fiber swells the stomach, increases the viscosity of the food mass, and delays emptying [17]. However, we did not observe glucose-lowering effect of the vegetable-first diet. Moreover, no synergistic effect was observed between eating meat before rice consumption and the timing of eating vegetables on blood glucose elevation. This result may have been due to the overwhelmingly low amount of dietary fiber in the green salad (approximately 1.3 g/side dish). Lettuce, cucumber, and tomato are standard ingredients in green salads, but do not appear to be suitable sources of dietary fiber. Therefore, root or hot vegetables with high-fiber content may be good choices. Kubota et al.[11] suggested that the pre-intake of protein or fat and dietary fiber before carbohydrate sources may have different effects on postprandial hyperglycemia and may have additive effects. The synergistic effect between a meat-first diet and a vegetable-first diet is an issue to be considered in the future.

In the present study, we found that the inhibitory effect of TE on postprandial glucose elevation was comparable to that of the meat-first diet. Aiba et al.[18] reported that TE increased urinal insulin excretion and suppressed postprandial blood glucose levels as much as the meat-first and vegetable-first diets. In this regard, they considered that TE stimulates incretin secretion. Our findings are, in part, consistent with these results. TE is a common method in Japan and has several benefits, including increasing chewing, secreting saliva[9], maintaining nutritional balance, reducing salt and fat intake, and increasing flavor diversity[8]. Therefore, TE may need to be reassessed as a dietary therapy.

In conclusion, we demonstrated that eating meat before the rice (a meat-first diet) reduced postprandial glucose elevation compared with the reverse regimen in young healthy participants. However, we could not confirm the advantage of eating vegetables before rice (vegetable-first diet). In addition, TE was comparable to the meat-first diet in terms of postprandial glucose elevation. In this study, we assessed only blood glucose levels; therefore, further detailed research may be needed.

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米飯，肉および野菜の摂取順が若年者の食後血糖値に及ぼす影響

松尾達博・檜垣俊介[1]・稲井玲子[2]

要　約

日本では2型糖尿病が主要な健康上の問題として認識されており，食後血糖値上昇は，糖尿病発症の初期兆候である．近年，ベジファーストやミートファーストと呼ばれる食事法が，食後血糖値上昇を抑えることが注目されている．これらは，野菜や肉をコメなどの炭水化物源よりも先に摂取する食事法である．本研究では，米飯，肉料理および野菜料理の摂取順が食後血糖値に及ぼす影響について，若年者を被検者として詳細に検討した．さらに，これらの食事法と日本人の伝統的な食べ方である三角食べとを比較した．被験者に米飯，肉料理，野菜料理の3つからなる食事を，全ての組み合わせ順で摂取させ，食後120分までの血糖値変動を調べた．その結果，米飯より肉料理を先に食べた場合（ミートファースト）で，その逆に比べて，血糖値上昇が低かったが，野菜料理については摂取タイミングによる影響は見られなかった．また，三角食べはミートファーストと同等の食後血糖値上昇抑制効果があることが確認された．これらは，糖尿病予防を目的とした安全で効果的な食事法として期待できるかもしれない．

[1]北海道文教大学人間科学部健康栄養学科，北海道恵庭市黄金中央5-196-1
[2]奈良女子大学生活環境学部食物栄養学科，奈良県奈良市北魚屋東町630-8263