Effect of Repeated Intake of Disaccharides on Glucose Metabolism and Insulin Secretion in Healthy Adults - Comparison between Sucrose and Maltose

Li-Qiang Qin, Jue Li, Yuan Wang, Pei-Yu Wang, Akio Sato, and Takashi Kaneko*

Department of Environmental Health, School of Medicine, University of Yamanashi, Shimokato 1110, Tamaho, Yamanashi 409–3898, Japan

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We observed glucose metabolism and insulin secretion in healthy young men after intake of large amounts of sugar. Ten subjects, with the randomized cross-over design, ingested sucrose or maltose solution hourly from 10:00 to 13:00 (75 g in 225 ml water per time). Plasma concentrations of glucose, insulin and c-peptide were measured in fasting, at 30 min after each intake and at 2 hr after last intake. Plasma glucose concentration increased after the first intake and decreased to the fasting level from the second intake. Plasma insulin and c-peptide concentrations increased from the first intake and retained throughout following intakes. Plasma concentrations of glucose, insulin and c-peptide were higher in maltose group than in sucrose group and the significant differences were observed after the last intake. In the present study, glucose concentration maintained in the normal range after intake of large amounts of disaccharide and insulin secretion responded well to this repeated intake of disaccharide, however, maltose tended to induce insulin resistance compared with sucrose.

Key words —— disaccharide, sucrose, maltose, glucose, insulin, c-peptide

*To whom correspondence should be addressed: Department of Environmental Health, School of Medicine, University of Yamanashi, Shimokato 1110, Tamaho, Yamanashi 409–3898, Japan. Tel. & Fax: +81-55-273-9557; E-mail: shinr@res.yamanashi-med.ac.jp

INTRODUCTION

It was reported that intake of snack containing high refined sugar evoked excessive insulin responses following lower plasma glucose level, compared with the intake of whole food with the same energy in health participant.[1)] In a survey of 4928 healthy young men, hypoglycemia occurred in 24.4% after 100 g glucose was ingested.[2)] The adverse effect of simple sugar ingestion on glucose metabolism was more remarkable in children.[3)] On the other hand, it is widely believed that consumption of large amounts of sugar increases aggressive behavior in juvenile delinquents and adults in prison settings.[4,5)] Adolescents and adults with antisocial personality also showed low level of plasma glucose and high secretion rate of insulin at the base and during a glucose tolerance test.[6,7)] Therefore, adverse behavior responses to ingestion of high candy have been reported repeatedly in the lay press.[8)] Together, it was hypothesized that aggressive behavior after intake of large amounts of sugar was caused by impairment of carbohydrate metabolism. However, we don't know whether the acute intake of high sugar increases insulin secretion and/or decreases plasma glucose concentration to an abnormal extent. In this study, we observed glucose metabolism and insulin secretion in healthy young men after intake of large amounts of single sugar. Sucrose and maltose, two kinds of disaccharide, were selected because sucrose is common table sugar and maltose is often used as a food additive.

MATERIALS AND METHODS

Ten male volunteers were recruited from the university community. Their ages ranged from 20 to 23 years (21.7 ± 1.3) and body mass index was 22.9 ± 3.0 kg/m^2. All subjects had no history of endocrine and metabolic disorders. The purpose and nature of study were explained to all subjects, and their written consents were obtained before participation. The protocol was approved by the ethical committee of University of Yamanashi.

After common diets of morning and lunch, all subjects ate the same balance diet (12.0 kcal/kg) containing 60% carbohydrate, 25% fat and 15% protein in the dinner at the study site which was described elsewhere.[9)] In the next morning, fasting blood was drawn from forearm between 9:00 and 9:30, and then sucrose or maltose (75 g in 225 ml

water per time) solution was ingested hourly from 10:00 to 13:00 under supervision within five min. Venous blood was drawn at 30 min after each intake and at 2 hr after last intake (Table 1). The process of blood collection every time was finished within five min. Blood samples were immediately centrifuged at 4°C and the plasma was stored at –80°C until analyses. Other foods and violent sports were forbidden during the sampling. The randomized cross-over design was performed with one week interval. In other words, 1 week later, those who had ingested sucrose solution were given maltose solution and vice versa. Plasma concentrations of triglycerides (TG) and free fatty acid (FFA) in fasting blood, and glucose, insulin and c-peptide at all time points were measured with commercial kits purchased from Wako Pure Chemicals (Osaka, Japan). All samples were analyzed in duplicate in the same assay.

Values were expressed as means ± S.D. Student's paired *t*-test was used for comparison. All *p*-values were derived from two-sided statistical test and $p < 0.05$ was considered significant.

Table 1. Summary of Study Design

The day before experiment		
Breakfast, Lunch		Common diets
Dinner		Balance diet
The day of experiment		
	Blood	Intake of sucrose/maltose
9:00–9:30	○	
10:00		○
10:30	○	
11:00		○
11:30	○	
12:00		○
12:30	○	
13:00		○
13:30	○	
15:00	○	

RESULTS AND DISCUSSION

Plasma TG concentrations were 73.6 ± 15.9 mg/dl and 73.0 ± 19.0 mg/dl, and plasma FFA concentrations were 0.42 ± 0.12 mEg/dl and 0.44 ± 0.14 mEq/dl in sucrose and maltose groups, respectively. No significant differences were found in two groups and all of the subjects were in the normal ranges (TG 50–149 mg/dl and FFA 0.14–0.85 mEg/dl). It is suggested that two groups had similar functions for the glucose metabolism.

Plasma concentrations of glucose, insulin and c-peptide were displayed in the Table 2. As our expectation, plasma glucose concentration significantly increased at 30 min after the first intake of both sucrose and maltose. It was close to fasting level from the second intake. Although plasma glucose concentration at 2 hr after last intake was low, it did not show significant difference from fasting level. According to the suggestion of hypoglycemia (< 3.0 mmol/l) by Virally,[10] no hypoglycemia appeared when the subjects repeatedly ingested so large amounts of sucrose or maltose solutions ($75 \times 4 = 300$ g, 1200 kcal) in a short time. To our knowledge, there was no study that the consumption of disaccharide was higher than that in the present study. Insulin secretion was stimulated by the increase of plasma glucose after the first intake in both groups, and retained throughout following intakes. Plasma insulin concentration decreased remarkably at 2 hr after last intake, but it was still higher than fasting level. It is suggested that insulin secretion responded well to repeated intake of disaccharide solutions. The excessive secretion of insulin did not occur after every intake of sucrose and maltose, which maintained plasma glucose concentration in the normal range. c-Peptide is cleaved from proinsulin during the course of insulin synthesis. Its plasma concentration provides a more direct insight into the function of β cell in pancreas islet than insulin itself because c-peptide does not to be extracted by liver.[11] In the present study, the secretion patterns of c-peptide were similar with insulin patterns in both groups. It indicates that β cell function and insulin activity were not affected in this experimental condition.

In general, plasma concentrations of glucose, insulin and c-peptide were higher in maltose group in the present study. When these intakes were repeated to the last time (300 g disaccharide was ingested), the significant differences were found in plasma concentrations of glucose, insulin and c-peptide between two groups. At 2 hr after last intake, c-peptide concentration was still significant higher in maltose group than in sucrose group. It is suggested that maltose trends to induce insulin resistance compared with sucrose. The possible mechanism is that sucrose is hydrolyzed to glucose and fructose, and maltose to two glucoses; however, the absorption of

Table 2. Plasma Concentrations of Insulin, Glucose and c-Peptide during Intakes of Sucrose or Maltose

		Fasting	30 min after intake				2 hr after
			1	2	3	4	last intake
Sucrose	Glucose (mmol/l)	5.3 ± 0.3	8.3 ± 0.8	6.0 ± 0.5	6.0 ± 0.4	5.0 ± 0.5	4.8 ± 0.6
	Insulin (μU/ml)	7.6 ± 2.6	58.0 ± 26.3	59.8 ± 14.1	62.2 ± 10.8	57.2 ± 11.8	37.8 ± 6.9
	c-Peptide (ng/ml)	1.7 ± 0.4	7.0 ± 1.6	7.6 ± 1.9	8.3 ± 2.1	7.2 ± 1.6	4.6 ± 1.7
Maltose	Glucose (mmol/l)	5.3 ± 0.4	8.7 ± 1.0	6.4 ± 1.3	6.0 ± 0.4	5.5 ± 0.3*	4.9 ± 0.5
	Insulin (μU/ml)	7.9 ± 2.6	67.0 ± 18.1	68.7 ± 15.6	63.7 ± 15.6	71.5 ± 11.5*	48.2 ± 15.7
	c-Peptide (ng/ml)	1.7 ± 0.7	8.0 ± 2.2	9.0 ± 3.2	9.1 ± 2.5	9.2 ± 2.3*	6.8 ± 1.6*

Values are means ± S.D. *$p < 0.05$, comparison with the corresponding time point of sucrose group.

glucose is more rapid than that of fructose in digest process. In an animal study, fructose brought about substantial insulin resistance and hyperinsulinemia, compared with glucose after 2-week feed.[12] It is interesting that insulin resistance was caused easily by acute intake of glucose and evoked remarkably by chronic intake of fructose. For long time, it is a popular belief that the effects of sucrose and maltose on insulin secretion and their effects on glucose tolerance test were similar.[13,14] Consequently, the structural difference of these two disaccharides was considered no physiologically significant. However, this finding demonstrates that the difference of sucrose and maltose should be taken into consideration when performing the research about carbohydrate metabolism.

In conclusion, glucose concentration maintained in the normal range after intake of large amounts of disaccharide and insulin secretion responded well to this repeated intake of disaccharide. On the other hand, maltose seems to tend to induce insulin resistance compared with sucrose.

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