Original Article

The impact of soluble dietary fibre on gastric emptying, postprandial blood glucose and insulin in patients with type 2 diabetes

Kang Yu MD[1], Mei-Yun Ke MD[2], Wen-Hui Li MD[3], Shu-Qin Zhang B.S.[4], Xiu-Cai Fang MD[2]

[1] *Department of Clinical Nutrition, Peking Union Medical College Hospital, Beijing, China*
[2] *Department of Gastroenterology, Peking Union Medical College Hospital, Beijing, China*
[3] *Department of Endocrinology, Peking Union Medical College Hospital, Beijing, China*
[4] *Department of Ultrasound Diagnosis, Peking Union Medical College Hospital, Beijing, China*

Dietary fibre plays an important role in controlling postprandial glycemic and insulin response in diabetic patients. The intake of dietary fibre has been shown to delay the gastric emptying in healthy subjects. The relationship between gastric emptying and postprandial blood glucose in diabetic patients with fibre-load liquids needs to be investigated. To investigate the impact of soluble dietary fibre (SDF) on gastric emptying, postprandial glycemic and insulin response in patients with type 2 diabetes. 30 patients with type 2 diabetes (DM) and 10 healthy subjects (HS) matched for gender and age were randomized to receive SDF-free liquid (500 mL, 500 Kcal) and isoenergetic SDF liquid (oat β-glucan 7.5 g, 500 mL, 500 Kcal) on two separate days based on a cross-over with 6-day wash-out period. Gastric emptying was monitored by ultrasonography at intervals of 30 min for 2 hours. Fasting and postprandial blood was collected at intervals of 30-60 min for 180 min to determine plasma glucose and insulin. Proximal gastric emptying was delayed by SDF-treatment both in DM (p=0.001) and HS (p=0.037). SDF resulted in less output volume in the distal stomach in DM (p<0.05). SDF decreased postprandial glucose (p=0.001) and insulin (p=0.001) in DM subjects. Postprandial glucose (r=-0.547, p=0.047) and insulin (r=-0.566, p=0.004) were negatively correlated with distal emptying of SDF in DM subjects. Distal gastric emptying was delayed significantly in DM subjects with HbA1c levels ≥6.5% (p=0.021) or with complications (p=0.011) by SDF, respectively. SDF improved postprandial glycaemia which was related to slowing of gastric emptying.

Key Words: diabetes, soluble dietary fibre, gastric emptying, blood glucose, plasma insulin

INTRODUCTION

Several studies conducted during the last decade have shown that viscous soluble fibre plays an important role in controlling postprandial glycemic and insulin responses because of its effect on macronutrient absorption from the gut.[1-4] The American Diabetes Association recommends that diabetic patients consume 14 g/1000 kcal/day of fibre to improve glycemic control and to prevent the development of type 2 diabetes, as well as cardiovascular disease.[5]

However, controversy and confusion still exist about the physiological effects of soluble dietary fibres on postprandial blood glucose and induction of satiety for patients with type 2 diabetes. Although the beneficial effects of soluble fibre on blood glucose control in diabetes have been well established, its detailed mode of action remains unclear.[6]

The intake of dietary fibre has been shown to delay the gastric emptying in healthy subjects.[7] Gastric emptying, among other factors, regulates the postprandial blood glucose response, and a delay in gastric emptying is associated with a lower postprandial blood glucose level. It has been suggested that lower postprandial glucose and insulin observed after the consumption of dietary fibre could be caused by reduced gastric emptying, mouth-to-caecum transit or delayed absorption of glucose in the small intestine.[8-10] It is hypothesized that soluble fibre addition to a liquid meal will lead to gel forming in the stomach, resulting in a substantial delay of gastric emptying. However, there is no consensus about the effect of soluble fibre supplementation on gastrointestinal transit in diabetic patients. Some older works designed to investigate this hypothesis have given conflicting results.[6] Hlebowicz's study revealed no difference in postprandial blood glucose response or gastric emptying after the ingestion of rye whole-meal bread compared with white

Corresponding Author: Dr Mei-Yun Ke, Department of Gastroenterology, Peking Union Medical College Hospital, Peking Union Medical College, Chinese Academy of Medical Sciences, No.1 Shuaifuyuan Wangfujing, Dongcheng District, Beijing 100730, China.
Tel: 8610-65253037; Fax: 8610-65253037
Email: submit.pumch@gmail.com
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wheat bread.[11]

Disorders of gastrointestinal motility are common complications in patients with diabetes mellitus and may involve the whole alimentary tract. Gastric motility in patients with diabetes mellitus has usually been quantified by measurement of gastric emptying. Some studies have established that gastric emptying of solid meals or nutrient liquid is abnormally slow in 30-50% of out-patients with long-standing Type 1 or Type 2 diabetes.[8] Disordered gastric motility in diabetes mellitus may be associated with upper gastrointestinal symptoms, changes in oral drug absorption, influence the pharmacokinetics of hypoglycemic, and alterations in glucose control. However, the potential impact of upper gastrointestinal motor function on postprandial glucose level has received little attention.

In an attempt to clarify this confusing picture, the present study was to investigate the impact of soluble dietary fibre (SDF) on gastric emptying, postprandial blood glucose and insulin in patients with type 2 diabetes.

MATERIALS AND METHODS

Participants

We recruited potential participants through hospital diabetes clinics and local diabetes society. We required them to be in the range of 18-75 years of age, have been diagnosed with type 2 diabetes more than two years before this study entry. None of the subjects had known gastrointestinal diseases, a previous history of abdominal diseases, or had undergone intra-abdominal surgery. None were taking any medication known to affect gastrointestinal motility. Potential participants were screened by two doctors from the Department of Gastroenterology and Department of Endocrinology, respectively, during a clinical assessment. The protocol for the study was approved by the Ethics Review Board of the Peking Union Medical College Hospital (PUMCH). A full explanation of the procedure was given to each subject. All subjects gave written, informed consent to take part in this study.

Protocol

The study was a prospective, randomized cross-over study (Figure 1). A randomization sequence list was provided by a statistician using SAS 6.12 software (SAS Institute, Cary, North Carolina, USA). All the participants were first admitted to the general clinical research center for three days (the base-line period), during which a detailed history was taken, physical examinations and laboratory tests were performed. After the base-line period, each of subjects was randomized to be studied two times. Subjects were not permitted to ingest alcohol, caffeine, orange juice or to eat restaurant food for at least 24 h prior to undergoing a study, and were not permitted to smoke on the day of the study. After an overnight fast, each of subjects received SDF-free liquid (fibre 0 g, 500 mL, 500 Kcal) and isoenergetic SDF liquid (oat β-glucan 7.5 g, 500 mL, 500 Kcal) on two separate days based on a cross-over order. There was an interval of 6 days wash-out period before each study, in which a SDF-free liquid (total amount of fibre less than 3 g/day) or a SDF liquid (total amount of fibre 35 g/day) was given to the subject according to the SDF-free test meal or SDF test meal, respectively. All diets were administered for each subject by a dietitian not involved in the study, who knew the contents of the test meals but did not interact directly with the subjects or other staff. Subjects were tested in a semi-seated position reclined backwards at 45° to the horizontal plane and not allowed to drink and eat during the 3 hours of the study. Gastric emptying was monitored by ultrasonography every 30 min for 2 hours after the test meal intake to calculate the gastric half-emptying time (T1/2), gastric retention volume and emptying volume. Fasting and 4 postprandial blood samples were collected at intervals of 30-60 min for 180 min to determine blood glucose and insulin. Plasma glucose was measured by the glucose oxidase method (Beckman Glucose Analyzer, Beckman Instruments, USA). Plasma insulin was measured by radioimmunoassay (Phadaseph Insulin RIA 100, Pharmacia Diagnostica, Sweden). Glycosylated hemoglobin A1c was measured with ion-exchange high-performance liquid chromatography (Bio-Rad Laboratories, USA).

Test drinks

Two isoenergetic 500 mL liquids were studied: a fibre-free drink with 0 g fibre supplement and a drink with 7.5 g oat β-glucan supplement (90% soluble fibre, Shanxi Academy of Agricultural Sciences, Taiyuan, China). Apart from the differences in fibre content, the energy, nitrogen and macronutrient content of the two formulas was identical (Table 1). Both of the test drinks were prepared in the research kitchen of the Department of Clinical Nutrition of Peking Union Medical College Hospital. The composition of the drinks was designed according to the dietary recommendation and guideline of American Diabetes Association (ADA)[5,9] and was calculated by using the standard software program based on Chinese Food Composition 2004 (Institute of Nutrition and Food Safety, China Center for Disease Control).[12]

Ultrasound evaluation of gastric emptying

The gastric emptying was measured by using 2-D real-time ultrasonography (Agilent-Image Point HX with 3.5 MHz sector transducer which can be used to measure the distance and area of stomach). All examinations were performed by the same ultrasound specialist who was blinded to the test drinks in order to avoid differences due to inter-observer variations. The gastric emptying was evaluated between 8:00 a.m. and 10:00 a.m. after an overnight fast. All subjects were in a semi-seated position reclined backwards at 45° to the horizontal plane.

The gastric emptying of proximal and distal stomach was measured as follows: (a) The cross-sectional area between xiphoid and umbilical was scanned by ultrasound. (b) To determine the location of the relationship between the stomach and surrounding organs (including diaphragm and spleen). (c) To determine the location of cardia, pylorus and gastric angle. (d) To determine the location of proximal stomach below cardia 3-4 cm, which the upper bound is diaphragm and the outside is spleen. (e) To determine the location of distal stomach. (f) The longitudinal (L), the horizontal (H) and the anteroposterior (A) diameters were measured (Figure 3 and Figure 4) to calculate the gastric half-emptying time (T1/2) and the proximal and distal stomach volume by using the ellipsoid approximation formula of V=4/3*π*L*H*A. Measurements were taken immediately before the liquid drink infusion was started (T0) and then at 30-min intervals during the 2-h after the test drink intake.

Statistical analysis

Data were analyzed by double entering using the statistical software EPIDATA 3.0 by two investigators and statistical analysis was performed with SAS 6.12 (SAS Institute, Cary, NC, USA). The distribution of data was analyzed for normality. Normally distributed data were expressed as mean (SD) and non-normally distributed variables as median (interquartile range, iqr). Two-way ANOVA was used for analysis of normally distributed numerical variables, Wilcoxon test for non-normally distributed numerical variables, and chi-square test for categorical variables. Two-sided $p<0.05$ was chosen as the level of statistical significance.

RESULTS

A total of thirty patients (17 men and 13 women) with type 2 diabetes aged 65.7±6.2 years (range 48-73) and ten healthy subjects (HS) with normal oral glucose tolerance and matched for gender, age and body mass index (BMI) participated in this study (Figure 2). At baseline, the two groups were comparable with regard to demographics data, BMI, body composition, self-rating anxiety scale (SAS), self-rating depression scale (SDS) and laboratory values except for fasting blood glucose and glycosylated hemoglobin A1c (Table 2).

The mean duration of diabetes was 10.3±5.9 years (range 3-20). None of the patients received insulin therapy. Four patients were treated with medical diet alone, and the other 26 patients were treated with prescribed oral hypoglycemic drugs in addition to diet. The dosage of the oral hypoglycemic drugs was not changed during the study. None of the patients suffered from severe acute diabetes related complications. Sixteen patients had chronic complications including 4 coronary heart diseases, 6 diabetic retinal diseases and 6 diabetic lower limb lesions.

All subjects completed the study as planned. None was excluded because of clinical intolerance. Two test drinks were well tolerated by all subjects and none described any symptoms especially digestive symptoms, (ie nausea, diarrhea, bloating or abdominal pain) before, during or after the tests. No subjects became hypoglycemic during the gastric emptying measurements.

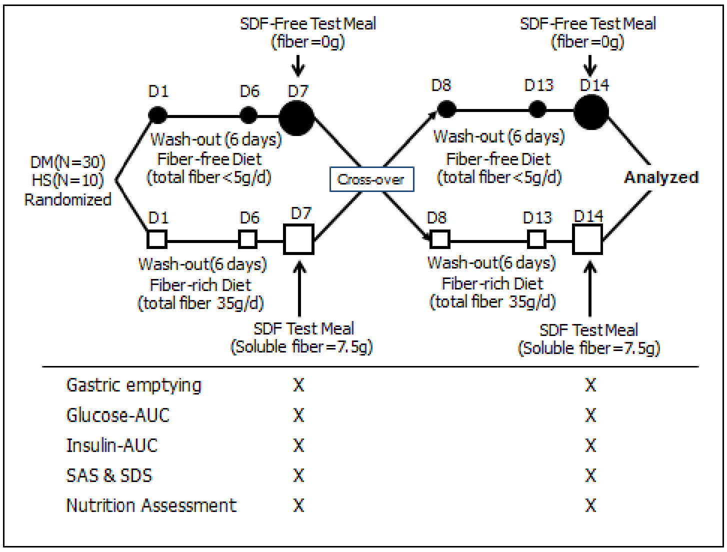

Figure 1. Study design: a randomized cross-over study. DM, diabetes mellitus; HS, healthy subjects; D1, day 1; D6, day 6; D8, day 8; D13 day 13; D14, day 14; SDF, soluble dietary fibre; AUC, area under curve; SAS, self-rating anxiety scale; SDS, self-rating depression scale.

Table 1. Composition of the two test meals

	SDF-free test liquid (500 mL)	SDF test liquid (500 mL)
Total energy	500 Kcal	500 Kcal
Energy density (kcal/mL)	1.0	1.0
Protein (% of total energy)	18.8 g (15%)	18.8 g (15%)
Nitrogen-caloric ratio	1 g: 166 Kcal	1 g: 166 Kcal
Fat (% of total energy)	16.7 g (30%)	16.7 g (30%)
Saturated fatty acid	2.5 g	2.5 g
Essential fatty acid	9.5 g	9.5 g
Carbohydrate (% of total energy)	68.8 g (55%)	68.8 g (55%)
SDF	0	7.5 g

SDF, soluble dietary fibre.

Table 2. Baseline characteristics of study participants in diabetes and healthy subjects

	HS (n=10)	DM (n=30)	*p* value
Gender (Male/Female)	5/5	17/13	0.731
Age (year)	62.6±3.5 (49-69)	65.7±6.2 (48-73)	0.183
Body mass index, BMI (kg/m^2)	24.1±2.8	24.2±2.5	0.498
Total body fat, TBF (%)	32.2±7.1	27.0±7.9	0.488
Waist/Hip ratio, W/H	0.97±0.36	0.91±0.24	0.310
Fasting blood glucose, FBG (mmol/L)	5.7±0.4	7.5±1.3	0.004
Glycosylated hemoglobin A1c, HbA1$_C$ (%)	5.7±0.3	6.8±0.8	0.047
Total cholesterol (mmol/L)	5.1±0.8	4.6±0.7	0.484
Triglycerides (mmol/L)	1.2±0.3	1.2±0.6	0.669
High density lipoprotein cholesterol, HDL-C (mmol/L)	1.4±0.3	1.3±0.3	0.665
Low density lipoprotein cholesterol, LDL-C (mmol/L)	3.2±0.6	2.6±0.7	0.983
Self-rating anxiety scale, SAS	32.7±7.5	33.7±8.4	0.660
Self-rating depression scale, SDS	35.6±10.3	38.5±11.3	0.420

DM: diabetes mellitus. HS: healthy subjects.

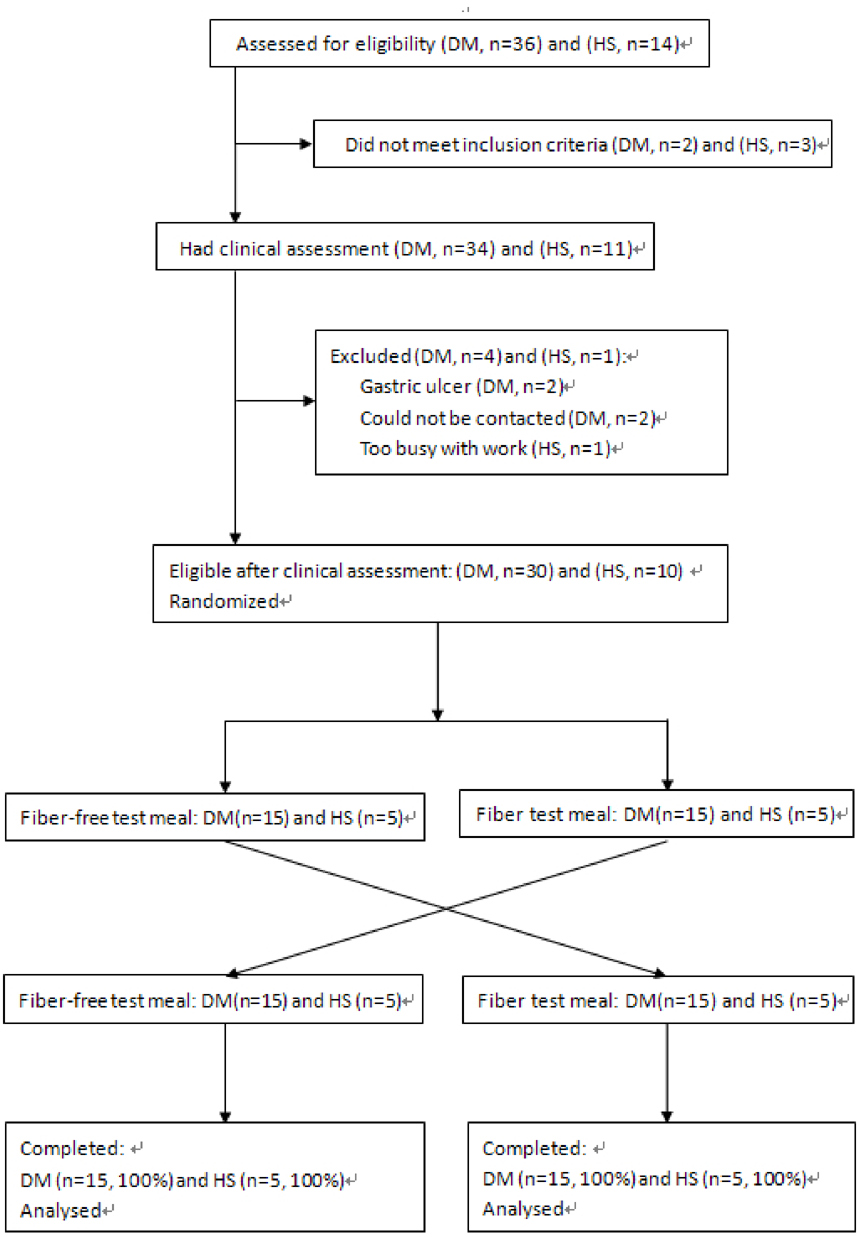

Figure 2. Flow chart showing patients enrollment in the study. DM, diabetes mellitus; HS, healthy subjects.

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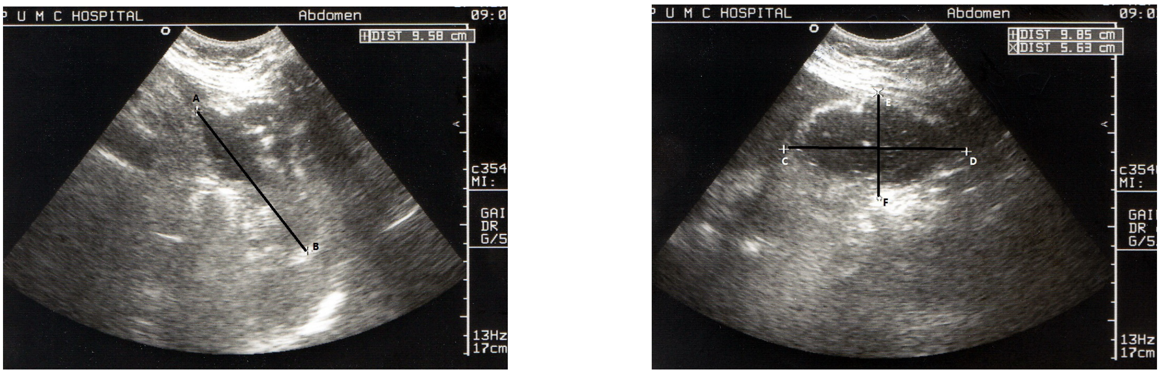

(1) The longitudinal diameter (AB=9.58 cm) of proximal stomach at 30 min after liquid intake. The longitudinal diameter is shown.
(2) The horizontal (CD=9.85 cm) and the anteroposterior diameters (EF=5.63 cm) of proximal stomach at 30 min after liquid intake. The horizontal and the anteroposterior diameters are shown.

Figure 3. Ultrasound images in subject number 1, demonstrating the cross-sectional area of the proximal stomach at 30 min after liquid intake.

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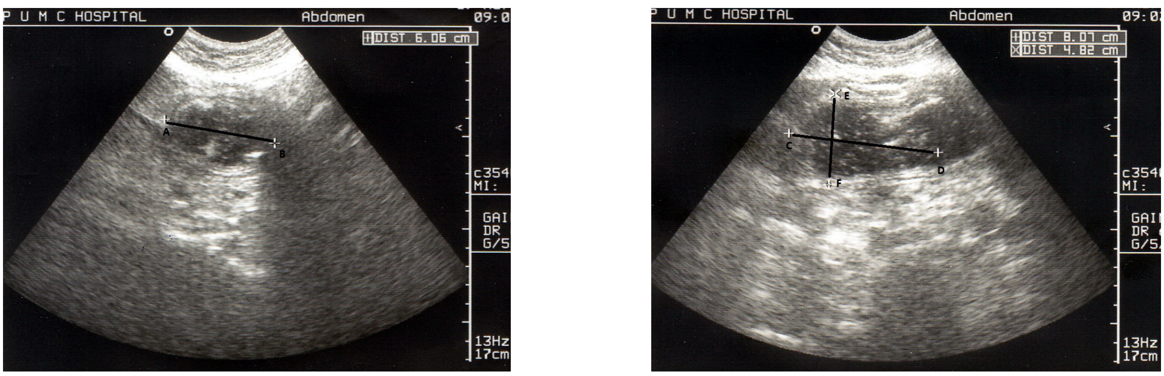
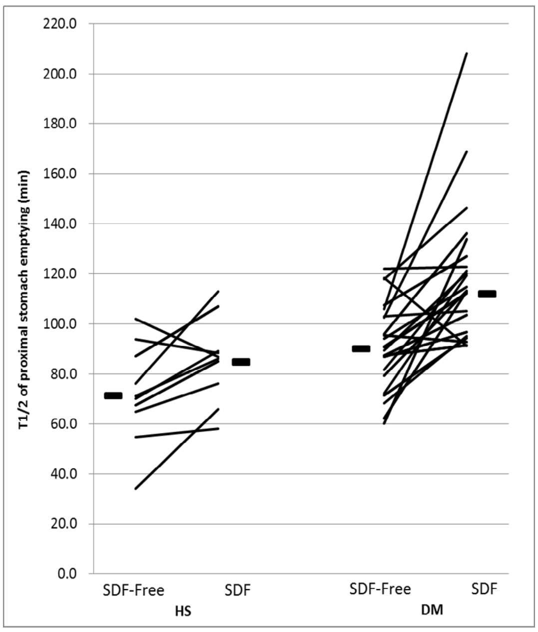


(1) The longitudinal diameter (AB=6.06 cm) of distal stomach at 30 min after liquid intake. The longitudinal diameter is shown.
(2) The horizontal (CD=8.07 cm) and the anteroposterior diameters (EF=4.82 cm) of distal stomach at 30 min after liquid intake. The horizontal and the anteroposterior diameters are shown.

Figure 4. Ultrasound images in subject number 1, demonstrating the cross-sectional area of the distal stomach at 30 min after liquid intake



(a) (b)

Figure 5. Effects of SDF compared to SDF-free meal in HS (a) and DM patients (b) on gastric half-emptying time (T1/2). SDF, soluble dietary fibre; HS, healthy subjects; DM, diabetes mellitus.

Gastric emptying

Compared with the SDF-free drink, the SDF drink delayed proximal gastric emptying significantly both in HS and DM characterized with prolonged T1/2 (HS, 72.1±19.5 min vs 85.5±16.5 min, *p*=0.037, Figure 5-a; DM, 91.0±16.8 min vs 114.5±34.4 min, *p*=0.001, Figure 5-b) Compared with HS, the T1/2 of proximal gastric emptying in DM group was prolonged significantly for both the SDF-free (*p*=0.008) and the SDF (*p*=0.037) drinks.

There was no difference in the volume change of distal stomach between SDF-free and SDF drinks in HS (Table 3). In DM patients, there was less output volume during 30-60 min (*p*=0.022) and 60-90 min (*p*=0.048) periods after the SDF drink (Table 3).

Postprandial plasma glucose and insulin response

SDF decreased the postprandial plasma glucose and insulin significantly in DM patients. There was no any significant difference observed in the HS (Table 4).

Table 3. The volume change of proximal and distal stomach of HS and DM after test drink intake

	HS (n=10)			DM (n=30)		
	SDF-free	SDF	*p* value	SDF-free	SDF	*p* value
Proximal stomach						
0-30 min (mL)	-65.1±60.4	-41.6±22.6	0.333	-59.9±35.1	-61.9±46.3	0.864
30-60 min (mL)	-64.0±61.0	-53.4±45.9	0.878	-61.4±50.6	-34.0±25.8	0.042
60-90 min (mL)	-69.3±27.4	-17.4±12.6	0.007	-58.8±54.2	-28.8±24.5	0.032
90-120 min (mL)	-58.7±35.2	-35.5±16.5	0.039	-37.9±28.2	-32.9±24.9	0.587
Distal stomach						
0-30 min (mL)	12.2±8.0	16.2±11.6	0.293	26.7±8.9	22.6±15.1	0.199
30-60 min (mL)	-10.1±15.9	-9.8±7.8	0.401	-19.8±10.6	-8.8±6.4	0.022
60-90 min (mL)	-19.1±18.3	-16.0±5.9	0.327	-17.3±7.6	-9.8±4.5	0.048
90-120 min (mL)	-18.9±4.5	-16.7±4.8	0.401	-12.9±4.2	-11.9±5.9	0.753

HS, healthy subjects; DM, diabetes mellitus; SDF, soluble dietary fibre.

Table 4. Effects of SDF compared to SDF-free liquid in HS and DM on blood glucose and plasma insulin

	HS (n=10)			DM (n=30)		
	SDF-free	SDF	*p* value	SDF-free	SDF	*p* value
Glucose						
Fasting (mmol/L)	5.6±0.7	5.7±0.5	0.632	7.8±1.7	7.6±1.4	0.334
Postprandial						
30 min (mmol/L)	8.7±1.7	8.8±2.7	0.754	14.1±2.3	10.8±2.2	0.001
60 min (mmol/L)	8.5±2.6	7.8±2.5	0.444	16.3±3.6	12.0±2.8	0.001
120 min (mmol/L)	7.2±2.2	6.6±2.1	0.269	14.2±5.2	10.6±3.1	0.001
180 min (mmol/L)	5.3±1.5	5.3±1.0	0.979	9.5±3.9	8.0±2.1	0.010
Insulin						
Fasting (mU/L)	4.5±2.5	4.3±1.7	1.000	8.4±7.6	7.7±7.5	0.297
Postprandial						
30 min (mU/L)	64.6±25.3	45.5±25.1	0.109	57.9±37.6	43.1±30.9	0.001
60 min (mU/L)	59.2±27.7	39.5±16.1	0.285	81.6±50.3	54.9±35.5	0.001
120 min (mU/L)	33.9±13.8	21.5±4.3	0.285	82.4±52.1	46.3±38.0	0.001
180 min (mU/L)	9.4±5.4	5.4±0.9	0.593	48.1±38.4	26.6±23.4	0.001

SDF, soluble dietary fibre; HS, healthy subjects; DM, diabetes mellitus.

Table 5. The correlation between the 120 min retention volume in distal stomach and plasma glucose/insulin response

		SDF-free liquid	SDF liquid
Glucose AUC	r value	-0.288	-0.547
	p value	0.173	0.047
Glucose AUCΔ	r value	-0.236	-0.461
	p value	0.268	0.023
Insulin AUC	r value	-0.094	-0.444
	p value	0.662	0.030
Insulin AUCΔ	r value	-0.092	-0.433
	p value	0.670	0.035

SDF, soluble dietary fibre; AUC: area under curve.
Δ: Difference between the 180 min after test liquid intake and 0 min.

Table 6. The effect of different factors on gastric emptying by SDF test drink in DM

	n	120 min retention volume (mL)		120 min emptying volume (mL)		120 min emptying rate (%)	
		proximal	distal	proximal	distal	proximal	distal
HbA_1c<6.5%	17	158.5±45.5	58.4±29.1	146.5±46.5	46.7±11.5	47.5±11.7	38.1±7.8
HbA_1c≥6.5%	13	174.2±69.0	72.9±15.2	174.6±74.4	27.2±13.9	50.5±12.1	33.7±14.3
p value		0.507	0.028	0.250	0.021	0.554	0.034
With complications	16	172.4±60.4	73.3±8.3	147.9±49.1	36.1±6.4	46.6±12.9	33.4±5.3
Without complication	14	150.3±44.4	52.7±13.1	177.0±77.6	66.4±9.9	53.1±7.8	58.1±6.9
p value		0.370	0.018	0.273	0.015	0.204	0.011

SDF: soluble dietary fibre; DM: diabetes mellitus; HbA1c: glycosylated hemoglobin A1c.

The correlation between the distal emptying and plasma glucose/insulin response

The 120 min retention volume in distal stomach was negatively correlated with glucose AUC (r=-0.547, *p*=0.047), glucose AUC delta (Δ) (r=-0.461, *p*=0.023), insulin AUC (r=-0.444, *p*=0.030) and insulin AUC delta (Δ) (r=-0.433, *p*=0.035) (Table 5).

The effect of different factors on gastric emptying

DM patients with HbA1c≥6.5% showed significant delayed distal gastric emptying with higher retention volume (*p*=0.028), lower emptying volume (*p*=0.021) and emptying rate (*p*=0.034) in DM patients following the SDF drink. Distal emptying in DM with complications was delayed with higher retention volume (*p*=0.018), lower emptying volume (*p*=0.015) and emptying rate (*p*=0.011) (Table 6).

DISCUSSION

There is already an extensive literature on the influence of fibre on gastric emptying and its inverse relationship with the regulation of postprandial blood glucose responses in response to various fibre rich nutraceuticals. But there might be some limitations with these older studies: first, most of the previous research studies were focused on Western populations whose dietary habits and background are different from Asians; second, although many studies observed the effects of fibre on blood glucose, they did not find any relationship with the change of gastrointestinal motility; third, some studies showed that the dietary fibre delayed the gastric emptying, but most of them were done in healthy subjects, and not in DM patients with gastrointestinal motility disorders. So the main purpose of our study was to investigate the impact of soluble dietary fibre on gastric emptying, postprandial blood glucose and insulin in Chinese patients with type 2 diabetes.

Our hypothesis was that soluble dietary fibre would lower the postprandial blood glucose response due to delayed gastric emptying. Dietary fibre is a complex of non-digestible carbohydrates and lignin that are intrinsic and intact in plants and are resistant to digestion and absorption in the small intestine.[10] In an attempt to explain the physiological effects of different types of fibre, dietary fibre has been divided into two groups, soluble and insoluble fibre. Soluble fibre is partially but not entirely water-soluble, and includes pectin, guar gum and glucomannan, psyllium, β-glucan and arabinoxylans.[11] Soluble dietary fibre promotes beneficial physiological effects such as laxation, reduction in blood cholesterol and postprandial blood glucose modulation.[6,7] Long term consumption of high soluble fibre diets has been shown to improve glycemic control of diabetic patients, but the overall energy and nutrients content of the diets were not kept constant.[13,14] To avoid the confounding effects of concomitant changes in energy and macronutrient, the two study drinks were isoenergetic and the macronutrient composition of the meals was identical except for the soluble fibre.

Several studies have shown that ultrasonography is effective for the evaluation of gastric emptying of liquid.[15] This method has the advantage of being the only validated, non-invasive procedure, which can be used to study gastric emptying under stationary conditions.[16] With identical experimental conditions, all examinations were performed by the same ultrasound specialist, so the differences due to inter-observer and intra-study variations were minimised.[17]

Although patients with diabetes are advised to increase the intake of dietary fibre, according to the China National Health and Nutrition Survey 2002, the averages daily intake of soluble dietary fibre was found to be only 5.5 g among diabetic patients in China.[18] In 2007, the American Diabetes Association recommends that diabetic patients consume 14 g/1000 kcal/day of fibre because a high amount of fibre is necessary to improve glucose control.[19] This amount is 2.5 times higher than that consumed by individuals in China. The main reason why the intake of fibre in patients with diabetes remains low is that the controversy about whether there are beneficial effects of soluble fibre on glucose control reduces the enthusiasm of physicians and dietitians for recommending high-fibre diets. In this study, we found that the soluble fibre supplement based on the ADA guideline improved the glucose control in patients with diabetes, as evidenced by significant decreases in the peak and the area under the curve (AUC) of postprandial plasma glucose and plasma insulin.

Potential factors governing postprandial blood glucose concentrations include:[20,21] (1) the rate of delivery of nutrients to the small intestine, (2) absorption of glucose from the small intestine, and (3) hepatic glucose metabolism. Gastric emptying is the major determinant of nutrient delivery to the small intestine.[20] Gastric emptying, among other factors, regulates the postprandial blood glucose response, and a delayed gastric emptying is associated with a lower postprandial blood glucose level. In patients with type 2 diabetes, a high dietary fibre intake could improve glucose control, and delayed gastric emptying is likely to be important in mediating this effect. Some studies have provided important insights into the complex relationship between upper gastrointestinal function and glucose control in diabetes.[11,22] It is now recognized that postprandial blood glucose concentrations are both a determinant of, as well as determined by, the delivery of nutrients from the stomach into the small intestine. In our study, gastric emptying was delayed by the soluble fibre drink in patients with diabetes, and diabetes with complications or with HbA1c≥6.5%. Upper gastrointestinal motor function, particularly the gastric emptying rate, is a major determinant of postprandial blood glucose concentrations, and there is increasing support for the concept that the modulation of gastric emptying could be used to optimize glucose control in diabetes.[11] Our study showed that postprandial glucose and insulin responses had negative correlation with distal emptying in soluble fibre liquid, which indicated that the mechanism of soluble fibre improving the postprandial blood glucose concentrations might be related to delayed gastric emptying.

In conclusions, our study showed that soluble fibre did improve postprandial glycaemia, which was related to the slowing of gastric emptying. Diabetes with complications or relative hyperglycemia showed significant delayed gastric emptying by soluble fibre liquid. These observations have potential implications for the investigation and management of blood glucose and gastric emptying in patients with diabetes. Further researches are needed for the safety and efficiency of soluble fibre use in symptomatic patients with diabetes or diabetic gastroparesis.

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AUTHOR DISCLOSURES

There are no conflicts of interest.

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Original Article

The impact of soluble dietary fibre on gastric emptying, postprandial blood glucose and insulin in patients with type 2 diabetes

Kang Yu MD[1], Mei-Yun Ke MD[2], Wen-Hui Li MD[3], Shu-Qin Zhang Chief technician[4], Xiu-Cai Fang MD[2]

[1]*Department of Clinical Nutrition, Peking Union Medical College Hospital, Beijing, China*
[2]*Department of Gastroenterology, Peking Union Medical College Hospital, Beijing, China*
[3]*Department of Endocrinology, Peking Union Medical College Hospital, Beijing, China*
[4]*Department of Ultrasound Diagnosis, Peking Union Medical College Hospital, Beijing, China*

可溶性膳食纤维对 2 型糖尿病患者胃排空、餐后血糖和胰岛素的影响

膳食纤维在控制糖尿病患者餐后血糖和胰岛素反应中扮演重要角色。膳食纤维延缓健康者胃排空。糖尿病患者摄入含纤维液体后胃排空与餐后血糖的关系需要进一步研究。本文旨在研究可溶性膳食纤维(SDF)对 2 型糖尿病胃排空、餐后血糖和胰岛素的影响。30 例 2 型糖尿病(DM)及 10 例性别和年龄相匹配的健康者(HS)被随机交叉在两个独立日分别接受无 SDF(500 毫升，500 千卡)及等能量含 SDF(燕麦 β-葡聚糖 7.5 克，500 毫升，500 千卡)液体试餐。两次试餐间有 6 天洗脱期。餐后 2 小时用 B 超每隔 30 分钟测定胃排空，并测定空腹及餐后 180 分钟内每隔 30-60 分钟的血糖及胰岛素。SDF 使 DM(p=0.001)及 HS(p=0.037)近端胃排空延迟，使 DM 远端胃排出量减少(p<0.05)。SDF 显著降低 DM 餐后血糖(p=0.001)及胰岛素(p=0.001)。DM 餐后血糖(r=-0.547, p=0.047)及胰岛素(r=-0.566, p=0.004)与远端胃排空呈负相关。HbA1c≥6.5%(p=0.021)或有并发症(p=0.011)的 DM 患者，SDF 显著延迟远程胃排空。SDF 改善餐后血糖与延迟胃排空相关。

关键词：糖尿病、可溶性膳食纤维、胃排空、血糖、血浆胰岛素