Glycemic Index of three Oral Nutritional Supplements in healthy adults: a single-blind crossover study

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Research

Keywords: nutrition supplement, glycemic index, insulin index

Posted Date: May 5th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-24988/v1

Abstract

Background: The main objective of this study was to evaluate the glycemic index (GI) and insulin index (II) of three oral nutritional supplements (ONS) in healthy adults.

Methods: A single-blind crossover study was conducted in 12 healthy adults. Fasted subjects consumed one of three treatments at each visit, with a one week wash out period between visits. Every subject received all treatments. Treatments included two newly developed ONS (powder A, powder B) as well as a positive control Nutren ® Diabetes (powder C). Blood glucose and insulin levels at 15, 30, 45, 60, 90, 120, 180 and 240 mins were measured after the volunteers consumed one of the treatments which all of containing 50g carbohydrates per serving. The Wolever method was used to compute the area under the curve (AUC) for blood glucose and insulin, and GI and II of three powders were obtained.

Results: Using the GI and II of 50g glucose powder as reference standard, the GI of nutrition powders A, B and C are 44, 54, 29, respectively, and the II of nutrition powders A, B and C are 163, 182, 119, respectively.

Conclusions: Among the two newly developed ONS formulas, powder A is more suitable as an ONS for diabetics.

Trial registration: This trial was registered on www.chictr.org.cn as ChiCTR2000031287 on 03/26/2020.

Background

Studies have shown that the risk of diabetes is positively correlated with the glycemic index (GI), which is a measure of relative rise in blood glucose levels after the consumption of carbohydrates [1]. In 2011, the International Diabetes Federation (IDF) updated and released the "guidelines for postprandial blood glucose management" which showed through evidence-based medicine that dietary interventions are the basis of diabetes treatment. It recommended the use of GI to evaluate the ability of carbohydrate rich food to raise blood glucose [2]. GI describes the ability of food to raise blood glucose levels, measuring the effect that food has on postprandial blood glucose [3]. Research shows that food with low GI absorbs slowly and releases energy continuously after entering the body, allowing for the peak value of glucose to be lower and less variation in postprandial blood glucose, helping to maintain blood glucose homeostasis [4]. GI was initially used in the selection of carbohydrate rich food for diabetic patients with the goal of minimizing wide fluctuations in blood glucose. Research has shown that diets with low GI foods have important value in the prevention and treatment of obesity, cardiovascular disease and a multitude of chronic metabolic diseases [5–6].

In this study, we selected one ONS for diabetes called Nutren ® Diabetes as a positive control, and two newly developed ONS. Using the internationally recognized standard AS4694-2007, we comupted the GI [7] and II of these three supplements to provide a reference for the research and development of more oral nutritional supplements for diabetic patients.

Methods

Subjects

In this study, a total of 12 healthy subjects (6 men, 6 women) were included. Inclusion criteria were as follows: (1) Age between 18 and 27 years old. (2) Body mass index (BMI) within 18.5–23.9 kg/m2. (3) Inability to fast for longer than 10 hours and therefore unable to complete the experiment. (4) Gastrointestinal disease. (5) Participation in other clinical trials within three months. The Ethics Committee of Shanghai Sixth People's Hospital approved the study protocol (ID: 2016 − 127). The study, along with its risks and benefits were fully explained to all participants. Written informed consent was obtained from all subjects prior to the study.

Study Design

We conducted a single-blind crossover design study (three 1-day study periods scheduled 1 week apart) at Shanghai Jiao Tong University Affiliated Sixth People's Hospital. Every subjects received the same treatments on the same day and had a 1 week washout period between two treatments. All of them were required to receive the three treatments.

Study Procedures

Subjects were recruited through university intern and the clinic volunteer roster. The day before the test day, subjects were asked to avoid excessive exercise, smoking or drinking. Subjects arrived in the morning after a 12-hour overnight fasting for a baseline venous blood draw to measure glucose and insulin concentrations. One of the four powders (3 were ONS, 1 was glucose powder) was made into 250 ml drinks. Subjects were asked to finish the drinks in 10 minutes. Additional venous samples were drawn at 15、30、45、60、90、120、180、240 min and were collected into vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ). During this period, subjects were not allowed to eat other food or medicine, but they can drink 100–200 ml water with a small amount of activity.

Treatments

Three powders were consumed by all subjects (Table 1) and were matched for 50 g of available carbohydrates(Av CHO). Powder A and Powder B are developed by Inner Mongolia Dairy Technology Research Institute Co., Ltd. Powder C (Nutren ® Diabetes) is developed by Nestle HealthCare Nutrition, Inc., as a positive reference.

Table 1
Energy and macronutrient composition of the test powders

Formula	Amount (g)	Energy(kcal)	Av CHO (g)	Protein(g)	Fat(g)	DF(g)
Powder A (Low GI)	104.9	1915	50	23.1	16.2	8.9
Powder B (Balanced)	86.7	1617	50	15.5	12.7	3.4
Powder C (Nutren ® Diabetes)	112.4	2069	50	23	22.5	9.8
Abbreviations: Av CHO, available carbohydrate; DF, dietary fiber;						

Outcome Measures

Serum glucose analysis was performed using a type 7600-020 Automated Analyzer (Hitachi, Tokyo, Japan). Serum Insulin was measured using the human insulin ELISA kit (Alpco Diagnostics, Salem, NH, USA).

Statistical Analyses

All the results were analyzed with SPSS 19.0 software package (SPSS Inc. Chicago, IL, USA). Descriptive summary statistics (mean ± s.e.m.) were performed for all variables at each time point for each powder. Incremental area under the curve (iAUC) for blood glucose and insulin were computed, ignoring the area below fasting. Differences in responses to the powders were analyzed by repeated measures ANOVA for main effects of time and test powder and the time × test powder interaction. Results were statistically significantly at P□0.05.

Results

All 12 subjects tolerated the study with no adverse events reported. The fasting blood glucose of the 12 subjects was within the normal range, and reached the peak height 30 minutes after taking the test products (Table 2, Fig. 1). The peak blood glucose in powder B was the highest.

Table 2
Glucose Levels

time	Powder A	Powder B	Powder C	Glucose powder
0 min	4.68 ± 0.42	4.46 ± 0.32	4.21 ± 0.35	4.54 ± 0.26
15 min	5.40 ± 0.57	5.48 ± 0.6	4.80 ± 0.45	6.33 ± 0.75
30 min	5.77 ± 0.77	6.07 ± 0.91	5.14 ± 0.52	7.26 ± 1.07
45 min	5.40 ± 0.73	5.22 ± 0.91	4.44 ± 0.73	6.36 ± 1.26
60 min	5.06 ± 0.82	4.41 ± 0.95	3.99 ± 0.65	5.81 ± 1.12
90 min	4.47 ± 0.69	4.47 ± 0.7	4.02 ± 0.51	4.6 ± 1.10
120 min	4.48 ± 0.53	4.42 ± 0.64	4.18 ± 0.43	3.76 ± 0.93
180 min	4.35 ± 0.32*#	4.53 ± 0.44	4.19 ± 0.38	3.75 ± 0.62
240 min	4.75 ± 0.34*	4.75 ± 0.46	4.62 ± 0.38	4.23 ± 0.46
*p < 0.05,compared with powder C;#p < 0.05compared with powder B				

At 180 and 240 min, glucose levels were significantly higher for powder A, compared with the powder C (Table 2). At 180 min, glucose levels were significantly lower for powder A, comparing with powder B (Table 2). The $iAUC_{0-120min}$ and $iAUC_{0-180min}$ of glucose were significantly lower after consumption of powder A and powder C, comparing with the glucose powder (Table 3).

Table 3
Incremental area under the glucose curve

time	Powder A	Powder B	Powder C	Glucose powder
2 h	59.72 ± 38.73*	74.08 ± 64.19	39.61 ± 30.38*	136.63 ± 81.43
3 h	63.44 ± 45.69*	88.61 ± 75.03	50.79 ± 43.3*	140.05 ± 84.67
4 h	69.12 ± 43.58	105.58 ± 79.24	68.14 ± 50.22	141.4 ± 86.37
*p < 0.05,compared with glucose powder				

There was no significant difference between the $iAUC_{0-120min,}$ $iAUC_{0-180min,}$ $iAUC_{0-240min}$ of glucose after powder B and glucose powder.

The fasting serum insulin of the 12 subjects was within the normal range, reaching peak height 30 minutes after taking the test powder (Table 4, Fig. 2). The peak value of serum insulin in powder B was the highest.

Table 4
Insulin Levels

time	Powder A	Powder B	Powder C	Glucose powder
0 min	7.99 ± 4.07	9.2 ± 5.49	9.17 ± 3.62	6.25 ± 2.13
15 min	37 ± 31.83	53.69 ± 29.52*	36.4 ± 21.55	37.86 ± 20.46
30 min	67.04 ± 36.52	111.71 ± 51.95*	63.52 ± 23.74	49.41 ± 26.89
45 min	65.43 ± 40.46	76.15 ± 35.68	55.76 ± 22.20	45.99 ± 20.97
60 min	55.9 ± 50.35	57.1 ± 19.3	46.20 ± 18.64	37.79 ± 17.99
90 min	50.38 ± 62.22	52.78 ± 30.64*	34.52 ± 13.44	30.65 ± 16.13
120 min	48.75 ± 49.05	39.1 ± 18.26	38.26 ± 13.63	17.25 ± 15
180 min	18.54 ± 14.28	15.85 ± 9.78	16.50 ± 8.83	5.08 ± 2.48
240 min	8.41 ± 6.81	8.6 ± 7.99	6.62 ± 4.18	4.27 ± 1.75
*p < 0.05,compared with powder C;				

There was no significant difference between serum insulin at any time point in powder A and powder C. At 15, 30 and 90 min, insulin levels were significantly higher for powder B, comparing with the powder C (Table 4).

The $iAUC_{0-120min}$ of insulin was significantly higher for powder B, comparing with the powder C (Table 5). There was no significant difference between the $iAUC_{0-120min,}$ $iAUC_{0-180min,}$ $iAUC_{0-240min}$ of glucose after consumption of powder A and glucose powder.

Table 5
Incremental area under the insulin curve

time	Powder A	Powder B	Powder C	Glucose powder
2 h	5426.20 ± 4315.32	6052.03 ± 2764.33*	3961.56 ± 1364.65	3331.51 ± 1329.48
3 h	6649.00 ± 5665.06	7166.80 ± 3282.77	5084.23 ± 1762.47	3677.24 ± 1481.45
4 h	6649.00 ± 5665.06	7402.95 ± 3356.77	5365.23 ± 1952.13	3693.04 ± 1502.16
* p < 0.05,compared with powder C;				

The ratio under the iAUC of insulin and glucose often indicates sensitivity of the body to insulin. The results are shown in Table 6. The ratio of insulin / glucose at each time point after the intake of the three powders was higher than that of glucose powder, and the ratio of powder B from 30 min to 180 min was significantly higher, comparing with that of glucose powder. The ratio of powder C from 30 min to 240 min was significantly higher than that of glucose powder.

Table 6
Area ratio under response curve of insulin and glucose of nutritional supplements

time	Powder A	Powder B	Powder C	Glucose powder
15 min	32.68 ± 20.17	83.02 ± 140.69	45.89 ± 28.14	18.18 ± 9.5
30 min	45.45 ± 18.67	72.18 ± 67.02*	56.79 ± 25.14*	16.72 ± 7.98
45 min	54.17 ± 25.74	85.11 ± 80.79*	73.69 ± 42.37*	17.66 ± 8.57
60 min	60.60 ± 30.77	98.54 ± 93.16*	93.45 ± 58.91*	19.8 ± 10.04
90 min	73.35 ± 31.50	123.87 ± 116.59*	123.97 ± 85.68*	24.30 ± 11.63
120 min	89.81 ± 35.28	142.00 ± 141.80*	152.89 ± 125.85*	28.16 ± 12.79
180 min	104.09 ± 40.37	148.04 ± 165.91*	188.93 ± 189.23*	30.49 ± 14.62
240 min	95.15 ± 45.99	137.01 ± 171.47	153.88 ± 206.68*	30.39 ± 14.64
*p < 0.05,compared with powder C;				

Discussion

A variety of healthy products and nutritional supplements have emerged in the market. In order to ensure the effectiveness, quality, and safety of the products, the National Health and Family Planning Commission published the following national standards in 2013: No.11 announcement「General rules for formula Food for Special Medical Purpose(FSMP)」(GB29922-2013) and 「Good Manufacturing Practice of Foods for Special Medical Purpose」(GB29922-2013). FSMP refers to food specially processed and prepared to meet the special needs of people with digestion and absorption disorders, metabolic disorders, limited food intake, or specific disease status for nutrients or meals. Such products must be taken alone or in combination with other foods under the guidance of a doctor or dietitian ". FSMP is mainly divided into three categories, namely, full nutrition formula (which can be used as a single nutrition source to meet the nutrition requirements of the target population), specific full nutrition formula (which can be used as a single nutrition source to meet the nutrition requirements of a target population with specific diseases or medical conditions) and non-full nutrition formula (which meets part of the nutrition requirements of the target population) [9].

The glycemic index (GI) was first proposed by Jenkins [8] in 1981; it represents a kind of food physiological parameter and is an effective index to measure the postprandial blood glucose response of human body after food intake. After food with high GI enters the gastrointestinal tract, glucose enters the blood rapidly due to its high digestibility and absorption rate, resulting in high peaks of blood glucose. The main mechanism of low GI food is to reduce postprandial blood glucose response and insulin response, increase satiety, reduce energy intake, inhibit the generation of free fatty acids, help in the

regulation of gastrointestinal hormones, and affect the blood glucose response of the second meal [10]. Insulin index (II) represents the ratio of postprandial insulin response of test food to reference food (glucose powder) [11]. Therefore, the guidelines of many countries suggest that diabetics choose foods with low GI and II.

The powder A and powder B proposed in this study are full nutrition formula under development, and the product types are low GI type and balanced type respectively. As a positive control of this study, powder C is a suitable nutrition preparation for diabetics currently on the market. The result shows that GI of powder C was 29, which was similar to that of official data, indicating that the test results are reliable. The GI of low GI type, powder A is 44, which belongs in the category of products with low GI. The GI of balanced type, powder B is 54. Taking into consideration the possibility of measurement error, powder B is between low and medium GI. Only the area under the 2-hour blood glucose curve of powder A and C was significantly smaller than that of glucose powder. In addition, II of powder A and C were lower than that of powder B. The area under the 2-hour insulin curve of powder B was higher than that of the other two powder, and the difference was statistically significant between powder B and powder C. When choosing the ONS formula for diabetics, we should consider that powder B has a large amount of insulin secretion and a relatively high glycemic index, while these two factors are low in powder A. Powder A is more suitable for diabetics. For those who do not require strict blood glucose control, the other two ONS formula can be used.

Conclusions

In conclusion, the determination of GI and II is an important index to judge whether an ONS formula is suitable for the diabetic population, which can provide reference opinions when giving suggestions to patients.

Abbreviations

GI:glycemic index; II:insulin index; ONS:oral nutritional supplement; FSMP:food for special medical purpose; Av CHO:available carbohydrates; iAUC:incremental area under the curve;

Declarations

Ethics approval and consent to participate

The protocol (No. 2016 – 127) and consent form was reviewed and approved by Ethics Committee of Shanghai Sixth People's Hospital. All participants provided written informed consent.

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

Shanghai Jiaotong University Affiliated Sixth People's Hospital has received funds and oral nutrition supplements for experiment from Inner Mongolia Dairy Technology Research Institute Co., Ltd. The funders had no role in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results. LHL, LYJ, HJY, LHX, GS and ZZF have no competing

Funding

This study was funded by the Inner Mongolia Dairy Technology Research Institute Co., Ltd,. and no role in the collection, analysis or interpretation of data nor in writing the manuscript.

Authors' contributions

GS,LHL equally contributed to conception and design of the study; ZZF, LYJ and LhX provided study oversight; HJY and LYJ developed powder A and powder B used for the study. LHL conducted the research, analyzed the data and drafted the manuscript. All authors read and approved the final manuscript.

Acknowledgements

We would like to thank all the participants.

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Figures

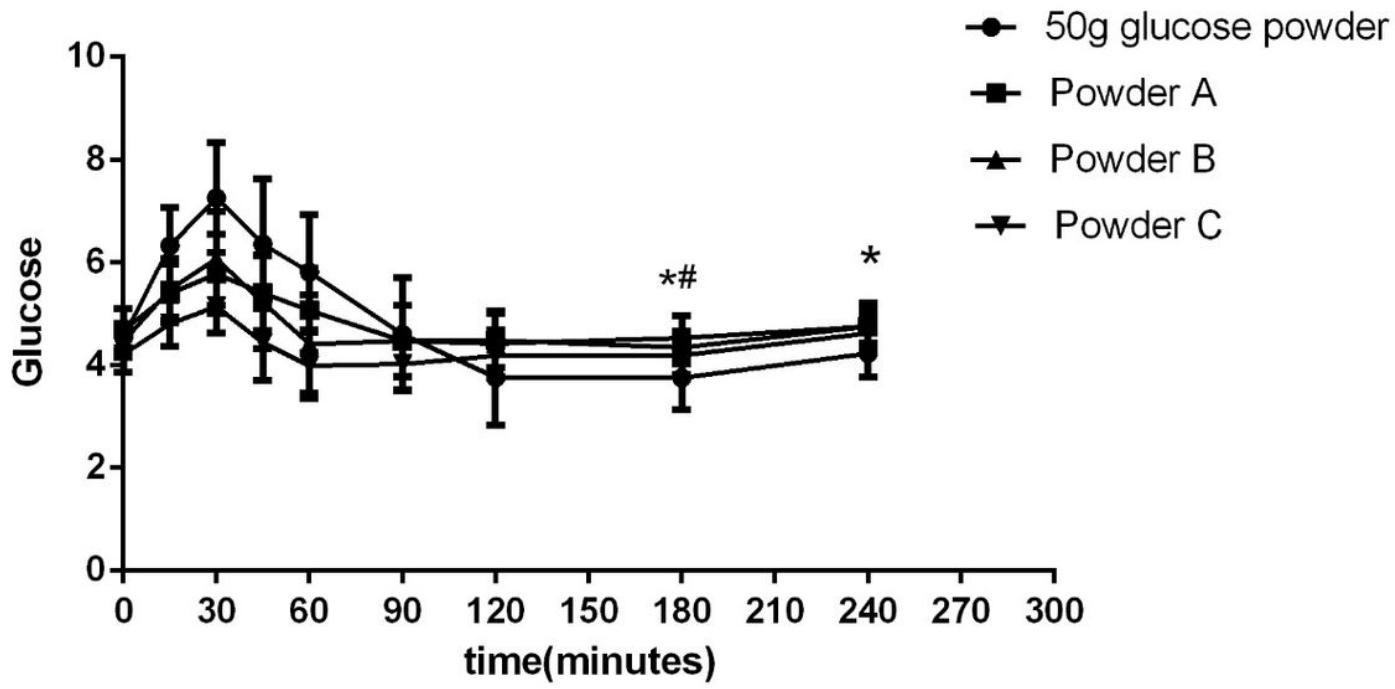

Figure 1

Effect of nutritional supplements and glucose powder on postprandial blood glucose response. *Powder A was significantly different from powder C (P<0.05). # Powder A was significantly different from powder B(P<0.05).

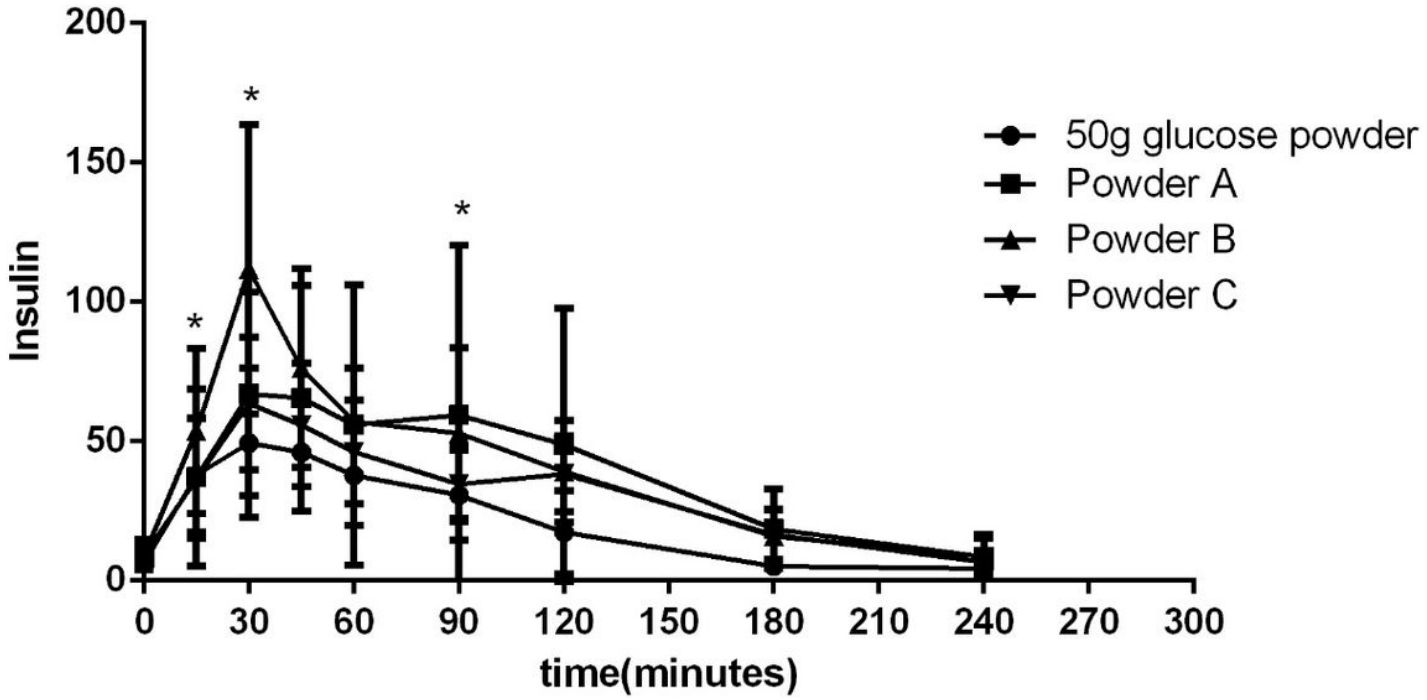

Figure 2

Effect of nutritional supplements and glucose powder on postprandial serum insulin response.*Powder B was significantly different from powder C (P<0.05).