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The effect of a low glycemic diet versus a standard diet on blood glucose levels and macronutrient intake in children with type 1 diabetes

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Abstract

A low glycemic index (GI) diet may lower postprandial hyperglycemia and decrease the risk for postabsorptive hypoglycemia in people with type 1 diabetes (T1D). However, insufficient evidence exists on the efficacy of a low GI diet to support practice recommendations. The goal of this study was to examine the blood glucose response to and the macronutrient composition of low GI (LGI) meals versus usual meals (UM) consumed *ad libidum* at home in children with T1D. A within-subjects, cross-over design was employed. Twenty-three participants were recruited between June and August, 2006. Participants wore a continuous blood glucose monitoring system (CGMS) and completed diet diaries on two days. On one day, participants consumed their UM; on another day, participants consumed LGI meals *ad libidum*. Order of the two days was counterbalanced. The mean GI was 34 ± 6 for the LGI day and 57 ± 6 for the UM day ($p<0.0001$). During the LGI day, mean daytime blood glucose values (125 ± 28 mg/dl vs. 185 ± 58 mg/dl, $p<0.001$), blood glucose area above 180 mg/dl (4486 ±6138 vs. 26707 ±25038, $p<0.006$) and high blood glucose index (5.1 ± 5.1 vs. 13.6 ± 7.6, $p<0.001$) were lower compared to the UM day. During the LGI day, subjects consumed more fiber (24.5 ± 12.3 g vs. 14.5 ± 6.1g, $p<0.007$) and less fat (45.7 ± 12.2 g vs. 76.8 ± 32.4 g, $p<0.005$); however, there were no differences in calorie, carbohydrate or protein intake. In this pilot study, a low GI diet was associated with improved diet quality and a reduction in hyperglycemia.

Keywords

type 1 diabetes; carbohydrates; glycemic index; children

Introduction

Nutrition therapy is an essential component of managing type 1 diabetes (T1D) in children. The goals of nutrition therapy are to maintain optimal metabolic outcomes (i.e. blood glucose levels, lipid profiles), to prevent and treat chronic complications of the disease, and to support growth and development (1).

The current American Diabetes Association's (ADA) dietary recommendations for T1D focus on counting carbohydrates and matching insulin doses to the grams of carbohydrate consumed in order to mimic normal pancreatic function and achieve near normal blood glucose (BG) levels (1). This regimen implies that equal carbohydrate portions have the same effect on BG; yet several factors, including the molecular structure of the carbohydrate, fiber content, and

degree of processing affect BG levels and result in differential BG responses to the same amount of carbohydrate (2). Carbohydrates with a low glycemic index (GI) provoke a slower, more sustained blood glucose response; therefore, a low GI diet has been proposed to improve glycemic control in children with diabetes (3-5). The GI assesses the blood glucose response to a fixed amount of carbohydrate from a food compared to the same amount of carbohydrate from glucose (6). In general, most vegetables (except white potatoes), most fruits, intact whole grains, and legumes have a low GI, while more refined and processed foods, such as white bread, typically have a high GI. The utility of a low GI diet in diabetes management remains controversial (7-9). Proponents of the diet believe that it may control BG better than current diet therapy (3-5,10,11). Alternatively, critics claim that it may limit food choice and increase fat intake (7,8).

Most of the research to date on low GI diets has been in overweight children (12-14) and few studies have been conducted in children with T1D (4,5,15,16). Recently a cross-over design study of children with T1D in the United States was published (16). The goal of that study was to determine the effect of low GI meals (mean GI 40) and high GI meals (mean GI 64) on blood glucose levels in a controlled setting. Participants demonstrated significantly lower daytime mean BG, BG area above 180 mg/dl, and high BG index when consuming low GI meals, but no differences were observed for the daytime BG area under 70 mg/dl, daytime low BG index, or for any nighttime parameters. That study was conducted in a highly controlled setting where all of the food was provided, macronutrient intake was kept consistent between conditions, and intake was monitored. Therefore, it is unknown whether the positive effects of a low GI diet observed in a supervised setting would be generalizable to a less controlled home setting where children choose what, when, and how much to eat.

The current study was conducted in conjunction with the above mentioned study (16). The first experiment determined the effect of high GI and low GI meals on BG levels in a controlled setting. The second experiment, whose results are reported in this paper, extended this research question to the home environment with *ad libidum* consumption by children, and further examined the effect of low GI meals on macronutrient intake. The purpose of this study was to determine the blood glucose response to and the macronutrient composition of low GI meals versus usual meals (UM) consumed *ad libidum* at home by children with T1D. The primary hypothesis was that blood glucose levels would be more favorable during consumption of low GI meals versus UM. No hypotheses were made regarding the effect on macronutrient consumption.

Methods

Recruitment

Children with T1D were recruited from a pediatric endocrinology practice in Baltimore, MD between June and August, 2006. Inclusion criteria were: diagnosis of T1D ≥ one year with insulin dose ≥ 0.5 u/kg/day and 7.0 to 16.9 years of age. Exclusion criteria were any other chronic disease and dietary restrictions that would preclude eating the food provided. A letter was mailed to families of eligible children and then a member of the research team followed up with a phone call to invite families to participate and answer questions. The study protocol was approved by the Institutional Review Board at the National Institutes of Health. Participants signed assent forms and their parents signed consent forms prior to participation.

Study procedures

The study employed a within-subjects cross-over design. Study participation lasted five days (3 days for the controlled feeding study followed by 2 days of at-home ad libidum consumption). Results from the two clinic days are published elsewhere. (16) Following the

clinic days, subjects were provided with instructions for the next two days of food consumption at home. On one of the days, subjects consumed their usual diet; on the other day, subjects were provided with low GI foods (GI ≤ 55) and instructions on what other foods they were allowed to eat (i.e. non-caloric beverages, fresh fruit) besides those provided. The foods provided are listed in Table 1. Both diets were consumed *ad libidum*; subjects chose when and how much to eat. Half of the subjects consumed their UM first, and half consumed the low GI (LGI) diet first.

Continuous glucose monitoring system

Blood glucose profiles were assessed using a continuous glucose monitoring system (CGMS) (Medtronic MiniMed, Northridge, CA), a portable device that measures interstitial glucose levels (which correspond to blood glucose levels). The CGMS is composed of two major components: a subcutaneous glucose sensor and a small, pager-type monitor. The glucose sensor is inserted into subcutaneous tissue, usually in the abdominal area. Measurements are taken every 10 seconds, and the average of the measures is recorded every 5 minutes. The CGMS sensor provides readings for up to three days, so the sensor was replaced after the third day.

Diet diaries

Subjects completed diet diaries at home on both days. A trained research assistant taught participants and their parents how to keep the diet diaries and provided them with a food diary booklet and instructions. Subjects were also called on the days following each diet condition and 24 hour diet recalls using a multiple-pass method were completed by a trained research assistant. The food diaries were used for subsequent dietary analysis unless a food item was unclear in the food diary, in which case the food item was clarified by the 24 hour recall. Macronutrient intake was calculated using the United States Department of Agriculture's food database (National Nutrient Database for Standard Reference, Release 16-1 and 17, Release dates July 2003 and 2004, Beltsville, MD) (17). The GI of foods was determined using published values obtained from standard testing procedures using glucose as a reference (18, 19).

Hemoglobin A1c

The most recent Hemoglobin A1c level, an indicator of blood sugar level over the previous 3 months, was obtained from the medical record.

Statistical Analyses

Continuous variables were described by means and standard deviations. Categorical variables were presented by frequency distributions. Summary values were calculated from the CGMS data beginning at breakfast and continuing until early morning the following day. Data were included if a minimum of 60% of the data was recorded by the CGMS. Day time and night time values were calculated for: 1) mean BG, 2) BG area above 180 mg/dl, and 3) BG area below 70 mg/dl. For BG area above 180 mg/dl and BG area below 70 mg/dl, the area under the curve was calculated using the trapezoidal rule (20). The day time interval began at the first food consumption and ended at 11:00 pm. The night time interval began at 11:00 pm and ended at 7:00 am or at the first food consumption the following day (whichever came first). Two measures of BG variability, the low blood glucose index (LBGI) and the high blood glucose index (HBGI) were also calculated for each time period. These recently-developed indices quantify the extent and frequency of glucose excursions (21). Both BG area above 180 mg/dl and the HBGI have been shown to be associated with HbA1c (20,22). Paired t-tests were used to assess differences in daytime BG levels, BG area above 180 mg/dl, BG area below 70 mg/dl, LBGI, HBGI, and macronutrient intake between the UM diet and the LGI diet. Statistical

significance was defined as $p \leq 0.05$. Statistical analyses were performed using STATA (Version 9.0, April 2005, StataCorp, College Station, TX).

Results and Discussion

Subjects

Twenty-three subjects (43% males, 13.1 years) participated in the study. Seven subjects had equipment failure (no data recorded, n=2 and insufficient data n=5) from the CGMS. The age of the 16 subjects with complete CGMS data was 13.1 ± 2.8 years (range 7.8 to 16.7 years) and 7 (44%) were males. The mean HbA1c was 8.9 ± 2.9 mg/dl. All participants were on a flexible basal-bolus regimen and the mean duration of diagnosis of T1D was 4.3 years. The racial composition was 65% Caucasian, 15% African-American, 15% Bi-racial and 5% Other.

Dietary Intake

The mean GI was 34 ± 6 (low GI) for the LGI day and 57 ± 6 (medium GI) for the UM day ($p<0.0001$). There was no difference in caloric intake between the LGI and UM days (1650 ± 452 kilocalories vs. 1882 ± 571 kilocalories, $p= 0.18$). During the LGI day subjects consumed more fiber (24.5 ± 12.3 g vs. 14.5 ± 6.1g, $p<0.007$) and less fat (45.7 ± 12.2 g vs. 76.8 ± 32.4 g, $p<0.005$), but there were no differences in carbohydrate (219 ± 94 g vs. 229 ± 92 g, $p=0.64$) or protein (90 ± 20 g vs. 78 ± 26 g, $p=0.20$) intake.

Blood glucose

During the LGI day, mean daytime BG values (125 ± 28 mg/dl vs. 185 ± 58 mg/dl, $p<0.0012$), BG area above 180 mg/dl (4486 ±6138 vs. 26707 ±25038, $p<0.0063$) and HBGI (5.1 ± 5.1 vs. 13.6 ± 7.6, $p <0.0013$) were lower compared to the UM day. There were no differences in the day time BG area below 70 mg/dl or in the nighttime BG values **(**Table 2).

These findings suggest that a LGI diet can improve daytime BG control in children with T1D without adversely affecting macronutrient consumption. In fact, on the LGI day, participants consumed more fiber and less fat, suggesting that a carefully planned LGI diet may improve diet quality. This is an important finding since the SEARCH for Diabetes in Youth Study reported low fruit, vegetable and whole grain consumption in youth with T1D (23). In the current study, subjects consumed 232 less calories on the low GI day which was not statistically significant; however, the study was not powered to detect this small of a difference in caloric intake.

This pilot study supports previous studies' findings of a positive effect of a low GI diet on blood glucose control in children with T1D (4,11,16). Although the approach used in the current study of providing low GI foods to children is not a realistic long-term approach, it does suggest the potential for adherence to a low GI diet, and demonstrated that when this diet was actually followed that it had a positive effect on BG control. The largest study to date in children with T1D was conducted in Australia and randomized 104 children to either a carbohydrate exchange diet or a low GI diet (4). After one year, the low GI group had better HbA1c levels and fewer episodes of hyperglycemia. There were no differences in insulin dose, hypoglycemic events or macronutrient composition of the diets between the groups. Additionally, children in the low GI group did not report more limited food choices than children who consumed a traditional carbohydrate-exchange diet (5). Due to differences in food products, food processing and dietary intake in different countries, longitudinal studies are needed in the United States to indicate the utility of a low GI diet in children with T1D.

The main limitation of this study was the high rate of CGMS equipment failure. Because the CGMS does not provide real-time data, any problems with the equipment could not be

determined until after each participant completed their data collection period and data were downloaded. Difficulties with several of the devices were encountered, and the devices were either repaired or replaced; however, data were still lost. Importantly, though, because the loss of data was due to problems with the devices themselves rather than subject behavior, the loss of data was likely random. Another limitation of this study was that the availability of certain foods that were provided to the participants (i.e. low GI bars, soy pasta) will vary by geographic location. Some low GI products may be more difficult to find in urban areas or small towns. However, there are enough low GI products that can be found in most grocery stores, particularly fresh fruits, vegetables, whole grains and legumes, that this should not be considered a major drawback of the diet.

The GI has been criticized as being a concept that is too complex for diabetes management and has limited clinical utility (7,8,24). Critics of a low GI diet believe that since so many factors affect the glycemic response to a meal that it would be too cumbersome for patients to classify foods according to their GI. Despite these concerns that ADA does recommend encouraging low GI foods that are high in fiber and other important nutrients (1). Clearly, it is not realistic to expect people to estimate the GI of every food they consume; rather they can be provided with an understanding of the general classification of foods as low, moderate, or high GI. Another criticism is that some low GI foods are high in fat which is particularly concerning for people with diabetes due to their risk of cardiovascular disease. However, this is not the case when focusing on whole, unprocessed low GI foods – vegetables, fruits, intact or minimally processed whole grains, and legumes – all of which are associated with improved cardiovascular health. GI is not purported to be the sole criteria by which to select a diet; but when considered along with nutrient density and other relevant factors may be a useful construct for improving dietary quality and blood sugar control.

Conclusion

The positive effect of a low GI diet in children with T1D was observed during *ad libidum* food consumption in the home environment in this pilot study. A low GI diet was associated with improved diet quality and decreased daytime hyperglycemia compared to the childrens' usual diets. However, since this was only a brief feeding study it is unknown whether children will adhere to this diet for a longer time period and what the long-term effects on blood glucose levels would be. These findings suggest that longitudinal studies to address these issues are warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. American Diabetes Association. Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. Diabetes Care 2007;30:S48–S65. [PubMed: 17192379]
2. Ludwig DS. The glycemic index: physiological mechanisms relating to obesity, diabetes, and cardiovascular disease. JAMA 2002;287:2414–23. [PubMed: 11988062]

3. Slama G, Elgrably F, Kabir M, Rizkalla S. Low glycemic index foods should play a role in improving overall glycemic control in type-1 and type-2 diabetic patients and, more specifically, in correcting excessive postprandial hyperglycemia. Nestle Nutr Workshop Ser Clin Perform Programme 2006;11:73–9.
4. Gilbertson H, Brand-Miller J, Thorburn A, Evens S, Chondros P, Werther G. The effect of flexible low glycemic index dietary advice versus measured carbohydrate exchange diets on glycemic control in children with type 1 diabetes. Diabetes Care 2001;24:1137–43. [PubMed: 11423492]
5. Gilbertson H, Thorburn A, Brand-Miller J, Chondros P, Werther G. Effects of low-glycemic-index dietary advice on diet quality and food choice in children with type 1 diabetes. Am J Clin Nutr 2003;77:83–90. [PubMed: 12499327]
6. Jenkins D, Kendall C, Augustin L, Franceschi S, Hamidi M, Jenkins A, Axelsen M. Glycemic index: overview of implications in health and disease. Am J Clin Nutr 2002;76:266S–73S. [PubMed: 12081850]
7. Beebe C. Diets with a low glycemic index: not ready for practice yet! Nutr Today 1999;34:82–6.
8. Franz MJ. In defense of the American Dietetic Association's recommendations on the glycemic index. Nutr Today 1999;34:81.
9. Chiasson JL. Glycemic index foods and glycemic control in type 1 diabetes. Curr Opin Endocrinol Diabetes 2000;7:30.
10. Collier G, Giudici S, Kalmusky J, Wolever T, Helman G, Wesson V, Ehrlich R. Low glycemic index starchy foods improve glucose control and lower serum cholesterol in diabetes children. Diabetes Nutrition and Metabolism 1998;1:11–9.
11. Fontvielle AM, Acosta M, Rizkalla SW, Bornet FJ, David P, Letanoux M, Tchobroutsky G, Slama G. A moderate switch from high to low glycemic-index foods for 3 weeks improves the metabolic control of type 1 diabetic subjects. Diabetes Nutrition and Metabolism 1988;1:139–43.
12. Spieth LE, Harnish JD, Lenders CM, Raezer LB, Pereira MA, Hangen S, Ludwig DS. A Low-Glycemic Index Diet in the Treatment of Pediatric Obesity. Arch Pediatr Adolesc Med 2000;154:947–51. [PubMed: 10980801]
13. Ludwig DS, Majzoub JA, Al-Zahrani A, Dallal GE, Blanco I, Roberts SB. High glycemic index foods, overeating, and obesity. Pediatrics 1999;103:e26. [PubMed: 10049982]
14. Ebbeling CB, Leidig MM, Sinclair KB, Hangen JP, Ludwig DS. A Reduced-Glycemic Load Diet in the Treatment of Adolescent Obesity. Arch of Pediatr Adolesc Med 2003;157:773–9. [PubMed: 12912783]
15. Kinmonth AL, Angus RM, Jenkins PA, Smith MA, Baum JD. Whole foods and increased dietary fiber improve blood glucose control in diabetic children. Arch Dis Child 1982;57:187–94. [PubMed: 6280621]
16. Nansel T, Gellar L, McGill A. Effect of varying glycemic index meals on blood sugar control assessed with continuous glucose monitoring in youth with type 1 diabetes on basal-bolus insulin regimens. Diabetes Care 2008;31:695–7. [PubMed: 18202243]
17. U.S. Department of Agriculture. Center for Nutrition Policy and Promotion. [April 22, 2008]. http://MyPyramid.gov
18. Foster-Powell K, Holt SH, Brand-Miller JC. International table of glycemic index and glycemic load values:2002. Am J Clin Nutr 2007;76:5–56. [PubMed: 12081815]
19. The University of Sydney. GI database. [April 22, 2008]. http://glycemicindex.com
20. Gross TM, Jeng LM, Antwerp BV, Fredrickson LP, Mastrototaro JJ. Hypo- and hyper-glycemic exposure estimates based on continuous glucose sensor data predict glycosylated hemoglobin. Diabetologia 2001;44:A170.European Association for the Study of Diabetes 37th Annual Meeting; Glasgow, UK.
21. Kovatchev BP, Clarke WL, Breton M, Brayman K, McCall A. Quantifying temporal glucose variability in diabetes via continuous glucose monitoring: mathematical methods and clinical application. Diabetes Technology & Therapeutics 2005;7:849–62. [PubMed: 16386091]
22. Kovatchev, BP.; Cox, DJ.; Straume, M.; Farhy, LS. Association of self-monitoring blood glucose profiles with glycosylated hemoglobin. In: Johnson, M.; Brand, L., editors. Methods in Enzymology. Vol 321: numerical computer methods, part C. New York: Academic Press; 2000. p. 410-7.

23. Mayer-Davis EL, Liese NM, Bell RA, Dabelea DM, Johansen JM, Pihoker C, Rodriguez BL, Thomas J, Williams D. SEARCH for Diabetes in Youth Study Group. Dietary intake among youth with diabetes: the SEARCH for Diabetes in Youth Study. J Am Diet Assoc 2006;106:689–97. [PubMed: 16647326]

24. Franz MJ. The glycemic index: not the most effective nutrition therapy intervention. Diabetes Care 2003;26:2466–8. [PubMed: 12882880]

Table 1

Low Glycemic Index Food Provided to Children with Type 1 Diabetes for *ad libidium* consumption at home

Meal[a]	Food	GI[b]
Breakfast	Applesauce, unsweetened	40
	Granola with oats, pumpkin seeds and flaxseeds	52
Morning Snack	Trail mix	
	Dried apricots	31
	Dried berries	22
	Peanuts	14
	Almonds	NA
Lunch	Health Valley Vegetable barley soup (barley, carrots, tomatoes, celery, peas, green beans)	25
	Turkey sandwich on Diabetes Lifestyles sprouted grain bread or wrap with lettuce and tomato	55
	Baby carrots, raw	16
Afternoon Snack	Solo low GI snack bar	25
Dinner	Nutrition Kitchen soy spaghetti (soybeans)	18
	Meatballs	NA
	Salad	NA
Evening Snack	Fruit crisp	
	Apple, pear, or peach	40
	Rolled oats, thick [or]	53
	Baked beans [or]	48
	Diabetes Lifestyles sprouted grain bread [with]	55
	Peanut butter [or]	14
	Hummus	6

[a] Participants were told that they could eat the provided foods at anytime of the day and that the menus were just recommendations for what foods to eat at each meal. They were also allowed to consume non-caloric beverages and fresh fruit.

[b] GI was based on glucose as reference.

Table 2

Blood glucose values for low GI (LGI) versus usual meals (UM) dietary conditions

		Day	Mean	Paired Difference	Standard Deviation	Standard Error	t[b]	p
Day[a]	Mean blood glucose, mg/dl	LGI	125.4	60.5	53.7	14.4	-4.1	0.001
		UM	185.9					
	Blood glucose area above 180 mg/dl	LGI	4485.4	22222.2	25558.0	6830.7	-3.3	0.006
		UM	26707.6					
	Blood glucose area below 70 mg/dl	LGI	1353.2	902.0	2401.4	641.8	1.4	0.180
		UM	451.2					
	High blood glucose index	LGI	5.1	8.5	8.2	2.1	4.0	0.001
		UM	13.6					
	Low blood glucose index	LGI	3.1	1.9	3.6	0.9	-2.0	0.070
		UM	1.2					
Night[a]	Mean blood glucose, mg/dl	LGI	145.8	33.6	64.1	18.5	-1.8	0.096
		UM	179.4					
	Blood glucose area above 180 mg/dl	LGI	13598.4	323.1	23681.8	6568.2	-0.1	0.961
		UM	13921.5					
	Blood glucose area below 70 mg/dl	LGI	1113.6	924.5	2285.1	633.8	1.5	0.170
		UM	189.1					
	High blood glucose index	LGI	8.3	2.4	12.1	3.1	0.8	0.450
		UM	10.7					
	Low blood glucose index	LGI	3.6	2.7	5.2	1.4	-1.9	0.080
		UM	0.9					

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[a] The day time interval began at the first food consumption and ended at 11:00 pm. The night time interval began at 11:00 pm and ended at 7:00 am or at the first food consumption the following day.

[b] Paired sample t-tests were used to assess differences between the 2 conditions.