Published in final edited form as:

J Pediatr. 2009 March ; 154(3): 455–458. doi:10.1016/j.jpeds.2008.09.040.

High and Low Glycemic Index Mixed Meals and Blood Glucose in Youth with Type 2 Diabetes or Impaired Glucose Tolerance

Lauren Gellar¹ and Tonja R. Nansel²

¹ Clinical & Population Health Research Division, University of Massachusetts Medical School, Worcester, MA

² Division of Epidemiology, Statistics and Prevention Research, Eunice Kennedy Shriver, National Institute of Child Health and Human Development, National Institutes of Health, Department of Health and Human Services, Bethesda, MD

Abstract

This cross-over pilot study tested blood glucose response to low and high glycemic index meals in 12 obese youth with type 2 diabetes or impaired glucose tolerance. Participants demonstrated significantly lower mean daytime blood glucose and a trend toward lower variability, suggesting a clinically relevant impact of reducing glycemic index.

Keywords

children; adolescents; diet; nutrition; dietary intervention; blood sugar; diabetes management

The incidence of type 2 diabetes (T2D) and impaired glucose tolerance (IGT) in youths is rapidly rising. Data from the 1999–2000 and 2001–2002 NHANES (1) indicates that the prevalence of IGT in the US adolescent population is 2.75 million with an additional 39 thousand diagnosed with T2D (1). Recent research has suggested the potential utility of dietary glycemic index (GI) for reducing postprandial hyperglycemia (2,3) and subsequent insulin demand (4,5).

Methods

A within-subjects cross-over trial investigated the effects of low versus high GI meals on blood glucose (BG). Obese youths between the ages of 7–16 years, diagnosed with T2D or IGT were recruited through a pediatric endocrinology clinic from June–August of 2006. Eligible youths were identified by their health care provider and referred to the study. Informed parent consent and child assent were obtained. The study protocol was approved by the National Institute of Child Health and Human Development Institutional Review Board.

Corresponding Author: Tonja R. Nansel, PhD, 6100 Executive Blvd, Room 7B13R, MSC 7500, Bethesda, MD 20892-7510, Phone: 301-435-6937, Fax: 301-402-0284, Email: nanselt@mail.nih.gov.
Edited by SD and WFB

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

There authors declare no financial disclosures or conflicts of interest.

Subjects were served a full day of high glycemic index (GI) and a full day of low GI mixed meals in a supervised clinic setting, matched for macronutrient content, in counterbalanced order (Table[H1]s I and II). Standard washout dinners (sandwich and chips) and snacks (cereal with milk) were consumed at home the evening prior to both conditions. The two conditions were separated by one day, during which participants consumed their typical breakfast and lunch at home, followed by the same wash-out dinner and evening snack. Subjects' BG levels were assessed using the Medtronic MiniMed Continuous Glucose Monitoring System. Continuous glucose monitoring (CGM) began in the fasting state and continued throughout the study period.

Daytime (8:00 am to 8:00 pm) and nighttime (8:01 pm to 7:59 am) mean BG were calculated. Because the extent of BG variability may be relevant in addition to overall BG (6), a measure of intra-day glycemic variability, four-hour continuous overlapping net glycemic action (CONGA4) was calculated. CONGA4 is defined as the standard deviation of the differences in BG for every 4-hour pair of values; higher values indicate greater BG variability (7). Paired-sample t-tests were used to test for treatment condition differences in mean BG and BG variability for each time period. Data analyses were conducted using SPSS version 13.0. Previous data on the effect of a low GI diet on BG in adults with T2D (8) indicated that 8 sets of paired data provide 85% power to detect a 15% difference in BG. Because we were unable to recruit 8 subjects for each diagnosis (T2D & IGT), data were combined for primary analyses, with subgroup analyses conducted for descriptive purposes only.

Results

Twelve youths participated in this study; data for 1 subject were not included due to CGM failure. Sample characteristics of the 11 subjects were as follows; all were obese (BMI above the 95th percentile for age and sex), 5 were diagnosed with T2D (2 on metformin and one on insulin plus glucophage) and 6 with IGT (all also diagnosed with acanthosis nigricans or PCOS), 4 were male and 7 female, 10 were African American and 1 Latino, age range was 7–15 years (mean=11.48), and mean HbA1c was 7.25 ± 2.85 (8.72 ± 3.57 for T2D and 5.78 ± 0.45 for IGT).

BG results are presented in Table III. The average daytime mean BG was significantly lower for the low GI condition compared with the high GI condition. Participants demonstrated a trend toward lower variability in BG during daytime hours for the low GI condition. There were no significant differences between conditions in mean BG or variability during the nighttime periods.

Subgroup analyses were conducted for descriptive purposes to determine the degree to which the pattern of findings was similar across diagnoses. Findings indicate a consistent pattern of outcomes across both groups (Table III), though not statistically significant for most outcomes due to the reduced sample size. A greater magnitude of difference in BG between conditions was observed for youths with T2D than for youths with IGT.

Discussion

The results of this study suggest that consuming a low GI diet may have a favorable impact on the BG among youths with T2D or IGT. The difference observed in BG was clinically relevant and if sustained could translate into meaningful health outcomes. These findings are consistent with a recent meta-analysis of low GI diets among adults with type 1 or 2 diabetes indicating a favorable effect (2). Additionally, findings are consistent with the few existing studies using CGM to assess effects of dietary GI – one conducted in 11 adults with T2D (8) and another in 20 youths with type 1 diabetes (9). Previous research has not addressed the utility of a low GI

diet in persons with IGT, though beneficial outcomes on weight and satiety have been observed in obese youths (10,11).

Limitations of this study include its small sample size and short duration. Research of longer duration with larger samples is clearly needed to determine the sustainability and long-term health effects of a LGI diet in youths with T2D and IGT. Additionally, adherence to the conditions outside of the clinic could not be assured. Strengths of this study include the use of CGM, the inclusion of youths with T2D or IGT, implementation within a controlled clinic setting, and the use of primarily unprocessed foods in the low GI dietary condition to ensure an accurate estimate of GI.

Research in adults has suggested that the incidence of T2D can be reduced through lifestyle interventions, preventing progression to T2D by as much as 58% (12). Findings from this study suggest that reducing dietary GI may be an important component of lifestyle interventions for prevention or management of IGT and T2D. Our findings are of particular importance given that children who develop disorders of glucose metabolism are likely to be a particularly high-risk group. Thus, the ability to demonstrate substantial differences in BG with a dietary change lasting a single day suggests that a low GI diet is a promising approach for achieving improved health outcomes.

Acknowledgments

The authors would like to thank David Greenberg, Donna Franz, Ellie Centenio, and the staff of Mt. Washington Pediatric Hospital for their assistance in the conduct of this study.

This research was supported by the Intramural Research Program of the National Institutes of Health, *Eunice Kennedy Shriver* National Institute of Child Health and Human Development.

Abbreviations

T2D	Type 2 Diabetes
IGT	Impaired Glucose Tolerance
GI	Glycemic Index
CGM	Continuous Glucose Monitoring
CONGA4	Four-hour Continuous Overlapping Net Glycemic Action
BG	Blood Glucose

References

1. Duncan DE. Prevalence of diabetes and impaired fasting glucose levels among US adolescents: National Health and Nutrition Examination Survey, 1999–2002. *Arch Pediatr Adolesc Med* 2006;160:523–8. [PubMed: 16651496]
2. Brand-Miller J, Hayne S, Petocz P, Colagiuri S. Low-glycemic index diets in the management of diabetes. *Diabetes Care* 2003;26:2261–2267. [PubMed: 12882846]

3. Ludwig DS. The glycemic index: physiological mechanisms relating to obesity, diabetes, and cardiovascular disease. *JAMA* 2002;287:2414–2423. [PubMed: 11988062]
4. Higgins JA, Brand Miller JC, Denyer GS. Development of insulin resistance in the rat is dependent on the rate of glucose absorption from the diet. *Journal of Nutrition* 1996;126:596–602. [PubMed: 8598543]
5. Byrnes SE, Miller JC, Denyer GS. Amylopectin starch promotes the development of insulin resistance in rats. *Journal of Nutrition* 1996;125:1430–1437. [PubMed: 7782895]
6. Hirsch IB, Brownlee M. Should minimal blood glucose variability become the gold standard of glycemic control? *Journal of Diabetes and Its Complications* 2005;19:178–181. [PubMed: 15866065]
7. McDonnell CM, Donath SM, Vidmar SI, Werther GA, Cameron FJ. A novel approach to continuous glucose analysis utilizing glycemic variation. *Diabetes Technol Ther* 2005;7:253–63. [PubMed: 15857227]
8. Brynes AE, Lee JL, Brighton RE, Leeds AR, Dornhorst A, Frost GS. A low glycemic diet significantly improves the 24-hour blood glucose profile in people with type 2 diabetes, as assessed using the continuous glucose MiniMed monitor. *Diabetes Care* 2003;26:548–549. [PubMed: 12547905]
9. Nansel TR, Gellar L, McGill A. Effect of varying glycemic index meals on blood glucose control assessed with continuous glucose monitoring in youth with type 1 diabetes on basal-bolus insulin regimens. *Diabetes Care* 2008;31:695–697. [PubMed: 18202243]
10. Spieth LE, Harnish JD, Lenders CM, Raezer LB, Pereira MA, Hangen SJ, Ludwig DS. A low-glycemic index diet in the treatment of pediatric obesity. *Arch Pediatr Adolesc Med* 2000;154:947–51. [PubMed: 10980801]
11. Ludwig D, Majzoub JA, Al-Zahrani A, Dallal GE, Blanco I, Roberts SB. High glycemic index foods, overeating, and obesity. *Pediatrics* 1999;103:e26. [PubMed: 10049982]
12. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM. Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 2002 Feb 7;346(6):393–403. [PubMed: 11832527]

Table 1

Meals served for high glycemic index dietary conditions

	GI*	CHO (g)	Protein (g)	Fat (g)	Kcal
Breakfast					
Corn flakes, ¾ c.	77	18	1	0	77
Oatmeal muffin (made with white flour and instant oatmeal) †	69	22	3	3.5	128
Orange juice, 6 oz.	52	20	1	0	85
Low-fat milk (1%), ¾ c.	32	10	7	2	89
Lunch					
Pizza					
Crust, 1/6 of 12" diameter	70	31	4	5	188
Mozzarella cheese, low-fat, ½ c.	NA	2	16	10	158
Tomato sauce, ¼c.	38	4	1	0	18
Watermelon, 1 ¼ c.	76	14	1	1	61
Afternoon Snack					
Pretzels, ½ c.	83	22	2	.5	76
Dinner					
Roasted chicken breast with skin, 1 c.	NA	0	40	10	264
Green beans, 1 ¼ c.	NA	11	2	0	47
Mashed potatoes, instant, 1 c.	85	28	4	5	166
Roll, white, soft, 2"	70	14	2	1	80
Angel food cake, 1/24 of 10" cake	67	17	2	0	72
Evening Snack					
Whole-grain snack bar, chocolate chip (Kudos brand)	62	20	7.7	4.8	79
Mozzarella string cheese, low-fat	NA	1	1	3.5	120
Daily Totals % of total calories	mean=64	239 (52%)	96 (23%)	48 (25%)	1714

* Data from the University of Sydney GI database (www.glycemicindex.com) was used to determine the GI of individual foods. Mean GI for each condition was calculated as a weighted mean based on the GI and the amount of carbohydrate provided by each food.

† These items were prepared using recipes developed for this study, with the GI calculated from the constituting ingredients.

Table II

Meals served for low glycemic index dietary conditions

	GI	CHO (g)	Protein (g)	Fat (g)	Kcal
Breakfast					
Fruit smoothie [‡]					
Strawberries, unsweetened, 1c.	40	20	1	0	77
Banana, ½ c.	51	18	1	0	69
Yogurt, sugar-free fat-free, 1/3 c.	24	6	3	0	37
Almonds, 7	NA	2	2	4	49
Oat bran muffin (100% oat bran) [†]	55	18	5	3	98
Lunch					
Chili					
Kidney beans, ½ c. [‡]	28	20	7	0	109
Corn, ½ c.	48	20	3	1	88
Ground beef, 7% fat, 3 oz.	NA	0	21	14	213
Tomato sauce, ½ c.	38	9	2	0	37
Apple, 1 small	40	16	0	0	63
Afternoon Snack					
Peach sorbet (whipped frozen unsweetened peaches) [‡]	42	14	1	0	54
Dinner					
Chicken & vegetable stir-fry					
Chicken breast, ¾ c.	NA	0	31	4	166
Stir-fry vegetable mix, 2/3 c.	NA	15	3	3	92
Canola oil, ½ T.	NA	0	0	7	62
Brown basmati rice, ¾ c.	55	34	4	1	162
Sprouted wheat bread (Diabetic Lifestyles brand), 1 slice	55	15	5	0	80
Black bean brownie ^{†‡} (made with black beans & prowashonupana barley flour)	35	17	1	3	88
Evening Snack					
Soy snack bar (Revival brand)	47	30	20	9	240
Daily Totals % of total calories	weighted mean=40	264 (51%)	108 (24%)	50 (25%)	1788

* Data from the University of Sydney GI database (www.glycemicindex.com) was used to determine the GI of individual foods. Mean GI for each condition was calculated as a weighted mean based on the GI and the amount of carbohydrate provided by each food.

[†] These items were prepared using recipes developed for this study, with the GI calculated from the constituting ingredients.

[‡] A Vita-Mix blender (Vita-Mix Corporation, Cleveland, Ohio) was used to prepare these foods. The fruit smoothie and the sorbet were blended from the whole foods listed. For the chili, ¼ c. of the beans were pureed to increase palatability. For the brownies, the beans were pureed and the flour ground from whole barley.

Table III

Blood glucose parameters by dietary condition

Total Sample		GI	Mean	SD	SE	t	p
Day	Mean blood glucose	H	127.5	51.1	15.4	4.0	.003
		L	105.5	41.9	12.7		
	Blood glucose variability	H	-23.5	27.5	8.3	-2.2	.057
		L	-15.5	20.5	6.2		
Night	Mean blood glucose	H	112.9	35.8	11.3	1.8	.103
		L	102.5	24.7	7.8		
	Blood glucose variability	H	3.8	17.6	5.6	.273	.791
		L	2.9	12.0	3.8		
T2D Subgroup*		GI	Mean	SD	SE	t	p
Day	Mean blood glucose	H	162.6	58.8	26.3	5.0	.007
		L	129.7	54.1	24.2		
	Blood glucose variability	H	-38.7	35.7	16.0	-2.1	.104
		L	-25.7	26.3	11.8		
Night	Mean blood glucose	H	134.7	49.8	24.9	2.4	.094
		L	112.8	39.6	19.8		
	Blood glucose variability	H	9.3	28.5	14.2	1.0	.403
		L	2.9	16.4	8.2		
IGT Subgroup*		GI	Mean	SD	SE	t	p
Day	Mean blood glucose	H	98.2	14.0	5.7	1.9	.118
		L	85.4	10.5	4.3		
	Blood glucose variability	H	-10.8	8.2	3.3	-0.9	.399
		L	-7.0	9.8	4.0		
Night	Mean blood glucose	H	98.3	13.4	5.5	0.5	.669
		L	95.6	4.3	1.7		
	Blood glucose variability	H	0.2	5.3	2.2	-0.8	.447
		L	2.9	10.0	4.1		

* Although the study was not adequately powered for separate analyses by diagnostic subgroups, subgroup analyses were conducted for descriptive purposes.