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

TONJA R. NANSEL, PHD[1]
LAUREN GELLAR, MS, CHES[2]
ADRIENNE MCGILL, MHS[3]

OBJECTIVE — The purpose of this study was to test the effect of high glycemic index (HGI) and low glycemic index (LGI) meals on blood glucose levels using continuous blood glucose monitoring in youths with type 1 diabetes.

RESEARCH DESIGN AND METHODS — A total of 20 youths on basal-bolus regimens consumed macronutrient-matched HGI and LGI meals 1 day each in a controlled setting in varying order following consumption of a standardized evening meal. Medtronic MiniMed Continuous Glucose Monitoring Systems were used to assess blood glucose (BG) profiles.

RESULTS — Participants demonstrated significantly lower daytime mean BG, BG area >180 mg/dl, and high BG index when consuming LGI meals but no differences for daytime BG area <70 mg/dl, daytime low BG index, or any nighttime values. Significantly more BG values <80 mg/dl were treated on LGI days.

CONCLUSIONS — Findings indicate that consumption of an LGI diet may reduce glucose excursions, improving glycemic control.

Diabetes Care 31:695–697, 2008

While American Diabetes Association recommendations for dietary management emphasize the amount rather than the source of carbohydrate (1), research suggests that a low glycemic index (LGI) diet may improve glycemic control (2–4). However, the utility of an LGI diet remains controversial (5), and it is unknown whether it affords meaningful benefit over careful insulin-to-carbohydrate dosing or whether dietary glycemic index could affect insulin dose. Two studies using continuous glucose monitoring system (CGMS) conducted with healthy adults (6,7) and another with adults with type 2 diabetes (8) suggest that an LGI diet confers a more favorable blood glucose (BG) profile. However, insufficient research exists in type 1 diabetes, particularly with contemporary insulin regimens. The purpose of this study was to test the effect of HGI and LGI meals on BG levels using CGMS in youth with type 1 diabetes on basal-bolus regimens.

RESEARCH DESIGN AND METHODS

— Participants were recruited from a pediatric endocrinology practice; inclusion criteria included diagnosis of type 1 diabetes ≥1 year, insulin dose ≥0.5 units · kg^{-1} · day^{-1}, and age 7–16 years. Informed consent and assent were obtained. The study was approved by the institutional review board of the National Institutes of Health. A within-subject crossover trial was used; participants consumed 1 day of HGI meals and 1 day of LGI meals in a controlled setting. The order of conditions was counterbalanced, with a washout day between and a standardized evening meal before each condition. Diets were matched for calories and macronutrients; mean glycemic index of the HGI diet was 64 (e.g., corn flakes, white bread, mashed potatoes) and of the LGI diet was 40 (e.g., peaches, kidney beans, brown basmati rice) (online-only appendix table [available at http://dx.doi.org/10.2337/dc07-1879]). Meal timing and activity levels were consistent across conditions. The CGMS (Medtronic MiniMed, Northridge, CA) was used to assess BG profiles. Subjects were given standard BG meters, and BG checks were performed before each meal and 2 h postprandial. BG values <80 mg/dl were treated with 15 g carbohydrate.

Daytime and nighttime values were calculated from the CGMS data for each of the following parameters: mean BG, BG area >180 mg/dl, BG area <70 mg/dl, low BG index (9), and high BG index (9). Frequency of hypoglycemia was calculated from BG meter data. Because insulin dose could vary based on application of the correction factor, and additional carbohydrate could be provided for hypoglycemia treatment, the ratio of actual insulin taken to carbohydrate consumed was calculated. Paired sample *t* tests were

From the [1]Division of Epidemiology, Statistics and Prevention Research, National Institute of Child Health and Human Development, National Institutes of Health, Department of Health and Human Services, Bethesda, Maryland; the [2]Clinical & Population Health Research Division, University of Massachusetts Medical School, Worcester, Massachusetts; and the [3]Department of Pediatrics, Growth and Nutrition Division, University of Maryland School of Medicine, Baltimore, Maryland.

Address correspondence and reprint requests to Tonja Nansel, PhD, 6100 Executive Blvd, Rm. 7B13R, MSC 7510, Bethesda, MD 20892-7510. E-mail: nanselt@mail.nih.gov.

Received for publication 22 October 2007 and accepted in revised form 10 January 2008.

Published ahead of print at http://care.diabetesjournals.org on 17 January 2008. DOI: 10.2337/dc07-1879. Clinical trial reg. no. NCT00545727, clinicaltrials.gov.

Additional information for this article can be found in an online appendix at http://dx.doi.org/10.2337/dc07-1879.

Abbreviations: BG, blood glucose; CGMS, continuous glucose monitoring system; HGI, high glycemic index; LGI, low glycemic index.

Table 1—*Comparison of BG indexes for HGI and LGI dietary conditions*

	Mean	SD	SE	*t*	*P*
Day					
Mean BG				5.2	<0.001
HGI	184.2	45.8	10.2		
LGI	137.6	36.5	8.2		
BG area >180 mg/dl				3.8	0.001
HGI	26,217.2	20,823.1	4,656.2		
LGI	9,203.3	11,287.4	2,523.9		
BG area <70 mg/dl				0.3	0.77
HGI	526.8	1,374.7	307.4		
LGI	423.4	826.3	184.8		
High BG index				4.7	<0.001
HGI	11.7	7.2	1.6		
LGI	4.8	4.6	1.0		
Low BG index				−1.0	0.32
HGI	1.1	2.5	0.6		
LGI	1.7	1.7	0.4		
Night					
Mean BG				−1.5	0.15
HGI	159.0	68.8	15.8		
LGI	181.0	64.1	14.7		
BG area >180 mg/dl				−1.0	0.33
HGI	10,084.0	15,256.9	3,500.2		
LGI	14,674.3	19,460.5	4,464.5		
BG area <70 mg/dl				1.2	0.23
HGI	613.4	1,515.3	347.6		
LGI	145.2	488.9	112.2		
High BG index				−1.2	0.23
HGI	8.2	9.6	2.2		
LGI	11.2	11.1	2.6		
Low BG index				1.4	0.18
HGI	2.3	4.4	1.0		
LGI	0.8	1.7	0.4		

conducted to assess differences between conditions on each continuous outcome except for hypoglycemia frequency, where a skewed distribution necessitated use of Wilcoxon's signed-rank test.

RESULTS — A total of 22 youths participated, although two participants experienced CGMS equipment failure. All subjects used a basal-bolus insulin regimen (65% insulin pump, 35% injections). The mean ± SD duration of diabetes was 5.3 ± 4.5 years, A1C was 8.3 ± 1.8%, and age was 13.1 ± 2.6 years, and 55% were female, 80% were white, and 20% were black or mixed race.

Under the LGI condition, BG levels were in the target range (70–180 mg/dl) 66% of the time versus 47% under the HGI condition ($P = 0.002$). Participants demonstrated lower daytime mean BG, BG area >180 mg/dl, and high BG index under the LGI condition (Table 1). No differences were observed in BG area <70 mg/dl, low BG index, and nighttime parameters. Mild hypoglycemia occurred more frequently during the LGI condition (one or more episodes in 13 subjects during LGI vs. 8 subjects during HGI, $P = 0.007$) (supplemental figure [available in an online appendix at http://dx.doi.org/10.2337/dc07-1879]). Comparison of actual insulin taken (including application of correction factor) to carbohydrate consumed (including hypoglycemia treatment) indicated a trend for lower insulin required during the LGI condition. During the HGI condition, participants took 1 unit of insulin for every 10.4 g of carbohydrate consumed. During the LGI condition, participants took 1 unit of insulin for every 12.3 g of carbohydrate consumed ($t = -2.07$, $P = 0.05$).

CONCLUSIONS — While the use of glycemic index to guide carbohydrate choice has been criticized as minimally beneficial (10), these findings indicate that it has utility for improving glycemic control to a clinically meaningful degree above that obtained by careful carbohydrate counting and contemporary insulin regimens. The LGI diet resulted in significantly lower mean daytime BG, as well as lower scores on two indexes of high BG risk, both which have been associated with A1C (11,12). This effect was observed despite a greater actual amount of carbohydrate being consumed per unit of insulin in the LGI condition. The absence of a difference in nighttime parameters supports the understanding that an LGI diet effects BG through reduction of postprandial excursions.

It is notable that a greater frequency of mild hypoglycemia was observed during the LGI condition. Therefore, insulin dose on an LGI diet may need to be reduced to prevent excessive hypoglycemia. Consistent consumption of an LGI diet may reduce insulin requirement while improving BG control, but careful attention should be given to BG monitoring and adjustment of insulin dose.

Strengths of this study include *1*) the use of CGMS to capture the BG profile, *2*) a controlled setting to ensure compliance and consistency across conditions, and *3*) a sample of youth using insulin-to-carbohydrate regimens. Primary limitations are the study's short duration and small sample size, precluding assessment of effect modification by disease duration or pubertal status.

This study adds to the evidence supporting the utility of an LGI diet in optimizing diabetes management. Furthermore, considering the prevalence of cardiovascular risk factors in youth with diabetes (13) and the increasing prevalence of comorbid type 2 diabetes (14), the additional benefits of an LGI diet shown in previous research (15–17) are also highly relevant. Promoting LGI eating may offer substantial health benefits to people with type 1 diabetes.

Acknowledgments— This research was supported by the Intramural Research Program of the National Institutes of Health, the National Institute of Child Health & Human Development.

The authors acknowledge Linda Zeitzoff, David Greenberg, Ellie Centenio, and Donna Franz of Mt. Washington Pediatric Hospital for their assistance in the conduct of this study.

References

1. American Diabetes Association: Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. *Diabetes Care* 30:S48–S65, 2007
2. Brand-Miller J, Hayne S, Petocz P, Colagiuri S: Low-glycemic index diets in the management of diabetes. *Diabetes Care* 26:2261–2267, 2003
3. Kinmonth AL, Angus RM, Jenkins PA, Smith MA, Baum JD: Whole foods and increased dietary fibre improve blood glucose control in diabetic children. *Arch Dis Child* 57:187–194, 1982
4. Buyken AE, Toeller M, Heitkamp G, Karamanos B, Rottiers R, Muggeo M, Fuller JH: Glycemic index in the diet of European outpatients with type 1 diabetes: relations to glycated hemoglobin and serum lipids. *Am J Clin Nutr* 73:574–581, 2001
5. Sievenpiper JL, Vuksan V: Glycemic index in the treatment of diabetes: the debate continues. *J Am Coll Nutr* 23:1–4, 2004
6. Brynes AE, Adamson J, Dornhorst A, Frost GS: The beneficial effect of a diet with low glycaemic index on 24 h glucose profiles in healthy young people as assessed by continuous glucose monitoring. *British J Nutr* 93:179–182, 2005
7. Hui L, Nelson EAS, Choi K, Wong GWK, Sung R: Twelve-hour glycemic profiles with meals of high, medium, or low glycemic load. *Diabetes Care* 28:2981–2983, 2005
8. Brynes AE, Lee JL, Brighton RE, Leeds AR, Dornhorst A, Frost GS: A low glycemic diet significantly improves the 24-h blood glucose profile in people with type 2 diabetes, as assessed using the continuous glucose MiniMed monitor. *Diabetes Care* 26:548–549, 2003
9. 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 Technol Ther* 7:849–862, 2005
10. Franz MJ: The glycemic index: not the most effective nutrition therapy intervention. *Diabetes Care* 26:2466–2468, 2003
11. Kovatchev BP, Cox DJ, Straume M, Farhy LS: Association of self-monitoring blood glucose profiles with glycosylated hemoglobin. In *Methods in Enzymology*, *vol. 321: Numerical Computer Methods*. Johnson M, Brand L, Eds. New York, Academic Press, 2000, p. 410–417
12. 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 (Abstract). *Diabetologia* 44 (Suppl. 1):A170, 2001
13. Rodriguez BL, Fujimoto WY, Mayer-Davis EJ, Imperatore G, Williams DE, Bell RA, Wadwa RP, Palla SL, Liu LL, Kershnar A, Daniels SR, Linder B: Prevalence of cardiovascular disease risk factors in U.S. children and adolescents with diabetes: the SEARCH for Diabetes in Youth Study. *Diabetes Care* 29:1891–1896, 2006
14. Libman IM, Becker DJ: Coexistence of type 1 and type 2 diabetes mellitus: "double" diabetes? *Pediatric Diabetes* 4:110–113, 2003
15. Collier GR, Giudici S, Kalmusky J, Wolever TMS, Helman G, Wesson V, Ehrlich RM, Jenkins DJA: Low glycemic index starchy foods improve glucose control and lower serum cholesterol in diabetic children. *Diabetes Nutr Metab* 1:11–19, 1988
16. Jarvi A, Karlstrom B, Granfeldt Y, Bjorck I, Nils-George L, Bengt OH: Improved glycemic control and lipid profile and normalized fibrinolytic activity on a low glycemic index diet in type 2 diabetic patients. *Diabetes Care* 22:10–18, 1999
17. Rizkalla SW, Taghrid L, Laromiguiere M, Huet D, Boillot J, Rigoir A, Elgrably F, Slama G: Improved plasma glucose control, whole-body glucose utilization, and lipid profile on a low–glycemic index diet in type 2 diabetic men: a randomized controlled trial. *Diabetes Care* 27:1866–1872, 2004