A Flexible, Low–Glycemic Index Mexican-Style Diet in Overweight and Obese Subjects With Type 2 Diabetes Improves Metabolic Parameters During a 6-Week Treatment Period

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OBJECTIVE — The aim of this study was to compare the effects of a flexible lower– and higher–glycemic index (GI) Mexican-style diet on biochemical data and BMI during a 6-week treatment period.

RESEARCH DESIGN AND METHODS — This study was a randomized, crossover design of two 6-week periods with a 6-week washout period between treatments. Subjects with type 2 diabetes ($n = 36$) with a BMI >25 kg/m^2 were selected. Fourteen subjects completed the study with eligible dietary records. Dietary instruction was provided on flexible diets with both a high and low GI. Fasting venous blood samples were taken at the start and finish of each dietary period, and biochemical data were analyzed. Multi- and univariate one-factor repeated-measures ANOVA were used to compare biochemical data.

RESULTS — Glycemic load and GI were lower during the low-GI diet, and dietary fiber was lower during the high-GI diet. The participants in the low-GI period consumed significantly fewer carbohydrates, such as white-wheat bread, white long-grain rice, potatoes, high-GI fruits, and carrots, and more carbohydrates, such as pinto beans, whole-meal wheat bread, and low-GI fruits than did participants in the high-GI period. There were no differences in the amount of carbohydrates consumed, such as corn tortillas and dairy products. At the end of the study periods, A1c was improved on the low- compared with the high-GI diet ($P < 0.008$).

CONCLUSIONS — We conclude that a low-GI diet, containing Mexican-style foods, may help to improve the metabolic control in type 2 obese diabetic subjects during a 6-week period.

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In Mexico, the incidence of diabetes has been increasing, and this epidemic is likely to continue to escalate. The prevalence of diabetes increased from 8.2% in 1993 to 11.8% in 2000. In Mexico City, the central and southern states, and among underprivileged people (including the Mexican Indians), the prevalence of diabetes increased to 14% (1).

It is well established that different types of carbohydrates produce different glycemic responses (2–5). The glycemic index (GI) and glycemic load (GL) have been proposed as a method of ranking foods on the basis of the incremental blood glucose response they produce for a given amount of carbohydrates (6–8). Although the predictor effect of the GI and insulin responses to mixed meals is controversial (3,9–11), there are significant associations between the GI and/or GL and control of blood glucose, despite the imprecision of the measures (8,12). Results from two large prospective studies, the Nurses' Health Study (7) and the Health Professionals' Follow-Up Study (13), showed a positive association between a high-GI diet and risk of developing diabetes.

On the other hand, there have been studies examining the incidence of type 2 diabetes in African Americans (14) that showed no association of GI and GL with diabetes risk. In a recent study conducted in Australian overweight subjects, eating a low-GI diet showed a reduction of A1c, triacylglycerol, and LDL cholesterol after 12 weeks of treatment (15). Another study using a low-GI diet in healthy French men demonstrated a reduction of fat mass and triacylglycerol after a 5-week period (16). However, we have not found long-term studies showing the effect of low-GI diets containing Mexican-style foods on either Mexicans or Mexican Americans with diabetes. The typical Mexican diet includes beans (legumes) and corn tortillas (traditionally made), which are foods with a low GI. However, in Mexico and in the U.S., current dietary guidelines for people with diabetes focus on lowering dietary fat and increasing carbohydrate intake but do not mention the GI (17,18).

The aim of this study was to compare the effects of a lower and higher GI and flexible Mexican-style diet on biochemical data and BMI during a 6-week treatment period.

RESEARCH DESIGN AND METHODS

Subjects

Thirty-six subjects with type 2 diabetes (age, 53 ± 9 years; range, 35–75 years), and a mean diabetes duration of 8 ± 7

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Abbreviations: GI, glycemic index; GL, glycemic load.
A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

Table 1—*Reported energy composition, fiber, and GI of low- and high-GI diets (n = 14)*

	Low GI	High GI	*P**
Energy (kJ/day)	5,949 ± 239	6,530 ± 232	0.1
Carbohydrate (g)	214 ± 10.7	249 ± 10.7	0.02
Total fat (g)	36 ± 2.8	35 ± 2.4	0.80
Protein (g)	74 ± 3.1	69 ± 2.7	0.28
Sugar (g)	64 ± 3.4	72 ± 2.5	0.04
Fiber (g/day)	34 ± 2.1	25 ± 1.6	0.003
GI	44 ± 0.9	56 ± 1.3	0.0001
GL	86 ± 5.3	139 ± 7.3	0.0001

Data are means ± SEM. *Wilcoxon's sum-rank test.

years participated in the study. Twelve subjects (four on the low-GI diet) dropped out of the study, and 10 did not complete the dietary records. Fourteen subjects completed the study with eligible dietary records (59 ± 9 years; 44–75 years); of these, six were men and eight were women. Their BMI was 29.6 ± 5.8 kg/m^2, mean fasting glucose was 9.5 mmol/l, and mean A1c was 8.4%. The ethical committee of the Instituto de Nutrición de Baja California approved the study.

Study procedure

The study procedure consisted of a randomized, controlled, crossover design of two 6-week periods with a 6-week washout period between treatments. Dietary instruction was provided on flexible diets with both a higher and lower GI. Each participant entered a run-in period of 15 days before the start of the experimental diet, during which time they received their standard medications and were given detailed instructions, including a pamphlet, on lower- or higher-GI foods depending on randomization. Recommendations with respect to the amount of carbohydrates, which should be in the diet, were based on the number of portions of grain, fruit, vegetables, and dairy products recommended at the Apple of Health illustration guide (19). Subjects were randomly allocated to the lower- and higher-GI diets for a 6-week period in a crossover design (each subject received the two diets by random allocation to each diet) with a 6-week washout period. During the washout period, the habitual diet of each individual was used following the Apple of Health guide (19,20). Body weight was measured before and after dietary treatment periods.

Diets and dietary assessment

Typical lower-GI foods were oranges, beans (legumes), yogurt, pasta, and corn tortillas. Typical higher-GI foods were corn flakes, white bread, potatoes, and ripe bananas.

Participants completed unweighed dietary intake diaries for 1 day during the first, fourth, and sixth week of the two study periods, and computerized dietary analysis was done using Nutritionist Pro. The GI values are based on glucose as the standard taken from Foster-Powell's international table of GI (5). The average dietary GL for each participant was calculated by summing the products of the carbohydrate content per serving for each food times the average number of serving of that food times the GI for that food (21). GI was computed for each subject by dividing the GL by the total carbohydrate intake per day (21).

Blood analysis

Fasting venous blood samples were taken at the start and finish of each dietary period and were analyzed for glucose, A1c, total serum cholesterol, HDL, and triacylglycerol. For the quantitative determination of glucose in serum, the glucose oxidase procedure, based on a modified Trindler method, was used. Enzymatic determination was performed for total cholesterol, triacylglycerol, and HDL. LDL cholesterol was calculated using the Friedwald formula (22).

Statistical analysis

General lineal model with repeated measures was used to compare BMI and biochemical data from baseline to after the diet, because the same treatments were compared on the same participants. The between-subjects factor was the order of the diet treatment, and the within-subjects factor was the diet treatment (low- and high-GI diets). The Bonferroni test was used to adjust for multiple comparisons. A P value <0.05 indicated statistical significance. To compare carbohydrate food sources between low- and high-GI diets, Wilcoxon's rank-sum test was used.

RESULTS — Fourteen subjects completed dietary intake diaries for 3 days during the first, fourth, and sixth weeks of each of the two treatment periods. Most participants during the high-GI diet who dropped out of the study did so because of the perception of bad glycemic control or lack of acceptance of the diet. Compliance to the low-GI diet was high; only four participants dropped out of the study during this diet. Table 1 shows that the contribution to energy as protein, carbohydrate, sugar, and fat intake between the low- and the high-GI periods did not show statistical difference. Dietary fiber was significantly higher during the low-GI period ($P = 0.003$), and the GI and GL were significantly lower during the low-GI period ($P = 0.0001$).

Table 2—*BMI and metabolic characteristics of subjects at baseline at week 6 after low- or high-GI diet (n = 14)*

	Low-GI period		High-GI period		
	Baseline	6 weeks	Baseline	6 weeks	*P**
Fasting serum glucose (mmol/l)	10.1 ± 0.99	8.9† ± 0.66	10.9 ± 1.43	10.0 ± 0.99	0.04
A1c (%)	8.5 ± 0.28	8.1‡§ ± 0.24	8.6 ± 0.3	8.6 ± 0.24	0.02
BMI (kg/m^2)	32.4 ± 1.6	31.8‖ ± 1.6	32.3 ± 1.6	32.3 ± 1.6	0.05
Weight (kg)	91.6 ± 6.5	90.1¶ ± 6.2	92.6 ± 6.8	92.0 ± 6.6	0.04

Data are means ± SEM. *General lineal model (repeated measures) global results. Bonferroni test †$P = 0.03$ (low GI vs. high GI); ‡$P = 0.04$ (baseline, 6-week low-GI period); §$P = 0.001$ (low-GI vs. high-GI period); ‖$P = 0.04$ (baseline, 6-week low-GI period); ¶$P = 0.06$ (baseline, 6-week low-GI period).

Table 3—*Serum lipids changes in response to 6 weeks of low- or high-GI diet (n = 14)*

	Low-GI period		High-GI period		
	Baseline	6 weeks	Baseline	6 weeks	P*
Fasting total cholesterol (mmol/l)	5.4 ± 0.24	5.4 ± 0.23	5.6 ± 0.23	5.5 ± 0.24	0.5
LDL (mmol/l)	3.2 ± 0.16	3.2 ± 0.17	3.3 ± 0.2	3.4 ± 0.19	0.4
HDL (mmol/l)	1.22 ± 0.2	1.22 ± 0.4	1.24 ± 0.05	1.24 ± 0.06	0.78
Triacylglycerol (mmol/l)	1.99 ± 0.26	2.1 ± 0.21	2.2 ± 0.23	1.9 ± 0.19	0.13

Data are means ± SEM. *Repeated measures ANOVA.

BMI, A1c, and fasting serum glucose are shown in Table 2. BMI was lower during the low-GI period ($P = 0.054$), and A1c was also significantly lower after the low-GI period compared with after the high-GI period ($P = 0.019$). However, total, LDL, and HDL cholesterol, triacylglycerol, and fasting serum glucose did not show any significant changes after the dietary treatment periods (Table 3).

During the low period, participants consumed significantly less carbohydrates, such as white-wheat bread, white long-grain rice, potatoes, high-GI fruits (papaya, mango, banana, watermelon, and pineapple), carrots, and consumed more carbohydrates, such as pinto beans, whole-meal wheat bread, and low-GI fruits (pear, apple, apricot, orange, and nectarine), than did participants in the high-GI period. There were no differences in the amount of carbohydrate consumed as corn tortillas or dairy products (Table 4).

CONCLUSIONS — The study demonstrated that Mexican overweight and obese subjects with type 2 diabetes, who were given flexible dietary instructions based on cultural-based diets and low-GI choices achieved significantly better A1c levels after 6 weeks compared with those who received high-GI diets based on the Mexican dietary guidelines. Additionally, although there were differences in the consumption of different sources of food from grains, fruit, and vegetables, there was no statistical difference between the consumption of corn tortillas and dairy products in both diets.

The fact that a cultural-based flexible diet was given to the participants compensated the attrition, and therefore compliance was good when a high-fiber diet was given. The reported energy intakes are somewhat low, which might be the results of underreporting or to the low energy intakes in Mexican people with diabetes. Many low-GI foods, including beans, corn tortillas, pasta, and fruits, are part of the usual diet of Mexicans of a lower socioeconomic status. The fact that a flexible diet was given was particularly important for most of the participants, because they had already experienced a number of restricted diets. Other studies using flexible diets during a 12-month period with low-GI foods demonstrated beneficial effects on children with type 1 diabetes (23).

Additionally, this study showed a reduction of the BMI ($P = 0.054$) after the low-GI period. This is an important finding in a population with a high prevalence of diabetes (1) and child and adult obesity (24). A recent analysis of 26 studies showed that complex carbohydrates, regardless of their fiber content, have the greatest effect on satiety and also reduction in food intake (25). Buyken et al. (26) showed that low-GI food consumption was associated with low levels of A1c, independent of its fiber content.

One of the most interesting findings of this study was that subjects during both dietary periods consumed corn tortillas or dairy products the same during each dietary period. However, subjects in the low-GI period consumed less white bread, potatoes, white long-grain rice, and high-GI fruits (papaya, mango, banana, watermelon, and pineapple) and carrots, and consumed more pinto beans, whole-meal wheat bread, and low-GI fruits (pear, apple, apricot, orange, and nectarine) than did participants in the high-GI period. This may be the result of resistance toward changing specific foods, such as corn tortillas, which are the main staple food in a Mexican-style diet. The results on the consumption of dairy products were different than those observed in children with type 1 diabetes in Australia. In that study, subjects in the lowest GI quartile consumed more carbohydrates as dairy-based foods and whole wheat bread than did subjects in the highest GI quartile (27). As in our study, in the EURODIAB study dairy foods were not observed to be a major determinant of GI intake in the adult population (26).

Thus, despite the worldwide controversy of the advantages and disadvantages of using the low-GI diet criteria for the nutrition education in diabetes (18,28–30), this study provides evidence that more flexible Mexican-style instructions, with an emphasis on the use of low-GI foods, decreased BMI and improved the metabolic control in individuals with type 2 diabetes. Mexicans with type 2 diabetes and traditional food habits might benefit

Table 4—*Differences of carbohydrate (in grams) food sources between the low-GI and high-GI diets (n = 14)*

Carbohydrate source*	Low GI	High GI	P†
Corn tortilla	24 (0–74)	20 (0–89)	0.96
Atole (corn meal beverage)	0 (0–29)	0 (0–59)	0.009
White-wheat flour bread	0 (0–78)	25 (0–130)	0.0001
Whole-meal wheat bread	17 (0–64)	0 (0–43)	0.0001
Oats (instant)	0 (0–66)	0 (0–33)	0.064
White long-grain rice	0 (0–42)	10.5 (0–103)	0.0001
Potato (baked, boiled)	0 (0–31)	5 (0–96)	0.0001
Pinto beans	22 (0–66)	0 (0–31)	0.0001
Nopales (prickly pear cactus)	0 (0–21)	0 (0–7)	0.026
Carrots	0 (0–12)	3 (0–23)	0.002
Fruit low GI	46 (0–131)	8 (0–47)	0.0001
Fruit high GI	0 (0–75)	33 (0–86)	0.0001
Milk- and dairy-based foods	14 (0–43)	13 (0–41)	0.89

Data are median (range). *Median of total carbohydrate intake of food sources contributing 5% or more of carbohydrate intake. †Wilcoxon's rank-sum test.

from using the low-GI foods criteria. Although this diet helped to increase the adherence to the diet, it also promotes Mexican-style dishes, such as "frijoles and tortillas," increasing satiety as well as reducing body weight and improving metabolic control. Dietary recommendations for the treatment of Mexicans with type 2 diabetes may need to be reconsidered.

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