High-Carbohydrate, High-Fiber Diet in Children with Type I Diabetes Mellitus

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The effects of a high-carbohydrate, high-fiber (HCHF) diet on glucose control was evaluated in 12 children with type I diabetes mellitus. The children had had diabetes for an average of 5.25 yr; their mean glycosylated hemoglobin was 12.4% (normal 5–9%), and C-peptide was virtually undetectable in all but one. They were followed on a regular diabetic diet for 10 days at home and in the hospital and then were studied on a HCHF diet for 14 days. The HCHF diet contained 60% carbohydrate and 30 g of fiber per 1000 cal provided through grains, fruits, vegetables, and high-fiber crackers. Capillary blood glucose levels were monitored at home before meals and at bedtime, and venous plasma glucose levels were measured in the hospital before and after each meal and during the night. Plasma glucose was measured serially after test meals with each diet. There was no significant difference in blood glucose levels preprandially, postprandially, and while fasting on the two diets. The 24-h glucose profiles and posttest meal profiles obtained during both diets were remarkably similar. We conclude that a diet high in fiber and carbohydrate has limited application in children with type I diabetes mellitus who have no residual beta-cell function. DIABETES CARE 7: 63–67, JANUARY–FEBRUARY 1984.

High-carbohydrate, high-fiber (HCHF) diets have been shown to enhance diabetic control in both insulin-dependent[1–4] and non-insulin-dependent adults.[5–7] Using either vegetable fiber or resins and gums, these diets have resulted in improved glucose control and decreased doses of insulin or oral hypoglycemic agents in short[1,2,8,9] and relatively long-term studies.[2,4,10] However, despite predictions that use of such a diet would improve the glucose control of children with type I diabetes,[11] only one study has reported the effects of a HCHF regimen in a pediatric population.[12] Perceiving a need for more extensive testing of HCHF diets in a childhood population, we have studied the diabetic control in 12 children while on a regular diet and on a HCHF diet.

MEANS AND METHODS

Twelve children, 10–17 yr of age, were selected for the study on the basis of compliance rather than degree of control. They had had diabetes for 1–12 yr (mean = 5.25 yr) and were receiving an average insulin dosage of 0.92 U/kg/day in split doses. Three required 29–39 U of insulin per day, six required 40–49 U, and three required 50–69 U/day. Most had been testing their blood glucose at home with Chemstrip bG (Bio-Dynamics, Indianapolis, Indiana), the Dextrometer (Ames Division, Miles Laboratories, Elkhart, Indiana), or the Glucometer (Ames). None had been hospitalized in ketoacidosis for at least 6 mo and all were following a standard diabetes diet. Mean hemoglobin in A_{1c} at the start of the study was 12.4% (range 10–18.9%). Normal range is 5–9%. Informed written consent was obtained from the children or their parents before the study was started.

After receiving instruction and an individualized daily meal plan from our dietary staff, the children followed their usual diabetes diet for a week at home, monitoring their blood glucose with Chemstrip bG before meals and at bedtime. They were then admitted to the Clinical Research Center (CRC) for 3 days with strict dietary management and venous plasma glucose levels measured 1 h before and 1 h after each meal, at 2130 and 0200 h. On the third hospital day, test meals comparable to the meals the patients had received at home and during the first 2 days were provided. Plasma glucose levels were measured at 0, 30, 60, 90, 120, 180, and 240 min after breakfast and lunch. A serum C-peptide level was measured at 240 min. The children then were placed on a HCHF diet for 11 days at home and 3 days in the CRC

TABLE 1
Composition of diets

	Regular		High carbohydrate, high fiber	
	Mean	Range	Mean	Range
Calories (Kcal/day)	2236	1,200–3,500	2333	1,200–3,500
Fiber (g/day)	22	15–40	64	46–106
Carbohydrate (%)	46	42–49	60	58–63
Protein (%)	19	17–22	17	15–21
Fat (%)	35	30–39	23	20–32

with repetition of glucose and C-peptide measurements. There was no attempt to improve diabetic control by increasing exercise or altering insulin doses during the study.

Individualized meal plans were written for each participant. Each was on a three-meal, two-snack per day schedule. On the regular diet, based on their previous dietary habits, no specific fiber level was recommended. An analysis of the composition of the regular and HCHF diets is shown in Table 1. While on the HCHF diet, the children received 30 g of fiber per 1000 cal. The dietary fiber was in the form of vegetables (corn, peas, etc.), grains, fruits (berries, apples, and raisins), and high-fiber crackers. Approximately 18% of the fiber in the high-fiber diet came from the high-fiber crackers. Free choice foods contributed an average of 9% of the total fiber in the regular diet and 3.6% of the fiber in the HCHF diet. We chose not to use guar or cellulose in the diet because of unpalatability during our testing of these substances. We hoped through use of natural fiber foods to enhance acceptability of the high-fiber diet. Table 2 demonstrates a typical day's menu for the HCHF diet.

TABLE 2
Typical high-fiber meal plan

Breakfast	Lunch	3:00 p.m. Snack
Apple juice	Chicken noodle soup	Orange juice
All bran	Cheese sandwich with whole-meal bread	Unbuttered popcorn
Hard-cooked egg		
Fresh orange	Fresh raspberries	
2% Milk	2% Milk	
Dinner	**8:00 p.m. Snack**	
Baked chicken	Cottage cheese	
Rice	High-fiber crackers	
Green beans	Fresh raspberries	
Whole meal bread with butter		
Watermelon		
2% Milk		
Dietary fiber	**Total calories**	
70 g	2210	
17.5% Protein		
24% Fat		
62% Carbohydrate		

Venous plasma glucose levels in the CRC were determined by an automated glucose analyzer using the glucose-oxidase technique. Serum C-peptide levels were measured by Bio-Science Laboratories (Van Nuys, California) using a radioimmunoassay technique.

Differences in blood glucose values between the two study periods were analyzed using a paired comparison test giving t values as an expression of significant difference.

RESULTS

The average blood glucose levels during the home phase of the study are shown in Table 3. There was no statistically significant difference between the two diets, although there was a slight trend for higher blood glucose values while on the HCHF diet. Figure 1 demonstrates the marked similarities in blood glucose profiles obtained in the CRC while on the two diets. The differences in mean glucose levels while fasting (259 mg/dl with the regular diet versus 231 mg/dl with the HCHF diet), 1 h before meals (280 mg/dl versus 263 mg/dl), and 1 h after meals (352 mg/dl versus 324 mg/dl) were not significant ($P > 0.05$). If only our five patients with good and fair control (hemoglobin $A_{1c} < 12\%$) were examined, the results are still statistically insignificant ($P > 0.05$). Fasting values were 194 mg/dl on regular diet versus 160 mg/dl on HCHF diet, 1 h before meals 243 mg/dl versus 243 mg/dl, and 1 h after meals 322 mg/dl versus 320 mg/dl. The serial blood glucose levels after the test meals are illustrated in Figures 2 and 3. Once again, there is striking similarity between the two diets and no statistically significant differences ($P > 0.05$).

Mean stimulated serum C-peptide levels were 0.66 ng/ml during the regular diet test meal and 0.71 ng/ml during the HCHF diet test meal (normal range = 1.5–9.0 ng/ml). Only 1 of the 12 subjects had a C-peptide level that approached the lower limit of normal.

The children tolerated the HCHF diet relatively well with the main complaints being (1) feeling too full after a meal, (2) inability to finish all the food at a meal, (3) dislike for the high-fiber crackers, and (4) increased number of bowel movements. Their parents mentioned increased borborygmus and flatulence. Interestingly, 42% of the participants stated

TABLE 3
Capillary blood glucose levels at home

Time	Regular diet (mg/dl ± SEM)	High-carbohydrate, high-fiber diet (mg/dl ± SEM)
0730	178 ± 21	192 ± 26
1130	170 ± 23	184 ± 33
1630	184 ± 25	205 ± 24
2130	171 ± 28	184 ± 31

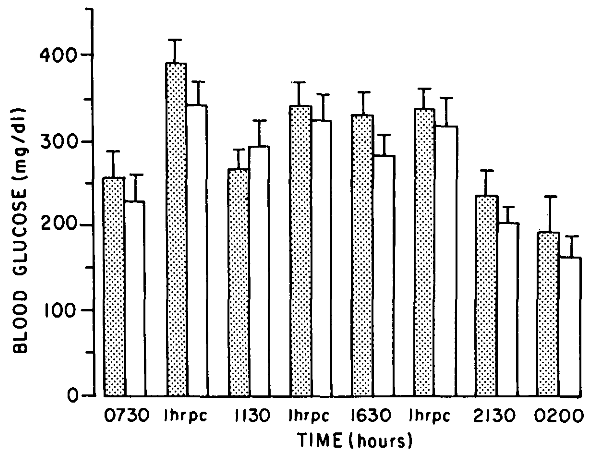

FIG. 1. *Venous plasma glucose profile during hospitalization. Bar represents mean blood glucose ± SEM for each set of values. Shaded bar = regular diet, open bar = high-carbohydrate, high-fiber (HCHF) diet, 1 hrpc = 1 h after meal.*

at least some interest in following a modified HCHF diet after the completion of the study because they felt it provided better control.

During the HCHF diet, there was no significant change in weight (mean = 47.34 kg before and 47.45 kg after the diet). There also was no change in the incidence of hypoglycemic reactions, and the average insulin dose was unchanged.

DISCUSSION

High-carbohydrate, high-fiber diets as adjunct therapy in diabetes have been explored since the early 1970s. In general, improved glucose tolerance and a reduction in antidiabetes medication dose has been reported when the diets have been employed.[11-15] Most of the studies reported have dealt with high-fiber supplements in adults with type II diabetes.[13] Several small studies have evaluated the effect of fiber supplements on insulin-dependent adults. The addition of 10 g of guar to a test meal (42% carbohydrate) given to six adults who were insulin dependent resulted in significant blood glucose reduction postprandially.[1] When 14–26 g of guar per day was added to a normal diabetes diet, there was a 38% decrease in mean urinary glucose and a slight decrease in mean blood glucose levels.[2] After 8 wk on this diet, six patients reported a 68% decrease in glycosuria and a 21% reduction in insulin requirement. Seventeen insulin-dependent adults given a 10–15-day diet containing 1 g of dietary fiber per 15 g of available carbohydrate had a significant reduction in glycosuria and postprandial blood sugar levels.[3]

In some studies the insulin doses have been reduced with the use of HCHF diets. Eight type II diabetic patients reported by Dodson et al.[14] (mean age = 44 yr) had an average insulin decrease of 9 U while on a HCHF diet. Anderson and Ward[10] provided a 70% carbohydrate, high-fiber diet to 20 insulin-dependent type II diabetic patients and found a 58% reduction in mean insulin dose. However, patients in this study[10] and in an earlier study[15] requiring more than 40 U/day did not have a significant change in dose. The majority of our patients (9–12) required more than 40 U of insulin per day and appear more comparable to the patients who failed to show a reduction in insulin dosage.

Most of the early studies failed to differentiate type I diabetes from insulin-requiring type II diabetes. Two recent studies address this difficulty. When 11 adults (mean age = 41 yr) with very low plasma C-peptide levels were placed on a high-carbohydrate diet, there was a significant decrease in mean basal and preprandial blood glucose levels, although the 24-h glucose profiles were not significantly altered.[16] Seven insulin-dependent male patients on the artificial pancreas with undetectable plasma C-peptide levels had a 12.4% reduction in insulin dose after receiving 5 g of guar before meals.[17] Thus, it appears that some type I diabetic patients may benefit from either high-carbohydrate or high-fiber supplementation in the diet.

Our study failed to demonstrate any significant improvement in hyperglycemia or any reduction in insulin require-

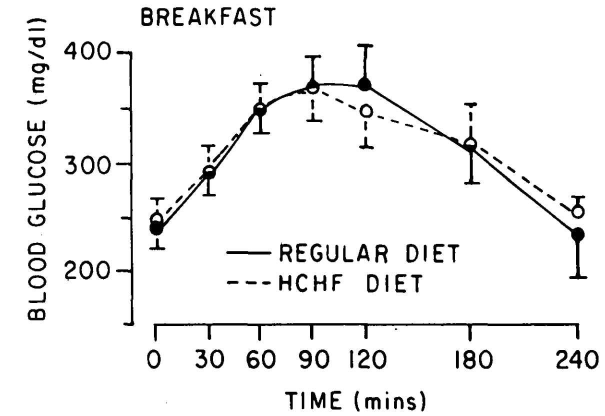

FIG. 2. *Mean venous plasma glucose (± SEM) during 4-h period after breakfast on regular and high-carbohydrate, high-fiber (HCHF) diet.*

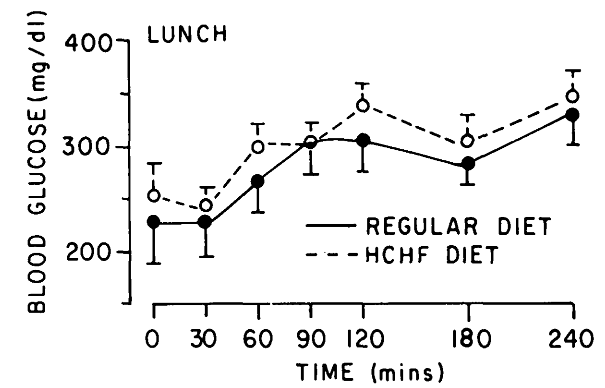

FIG. 3. *Mean venous plasma glucose (± SEM) during 4-h period after lunch on regular and high-carbohydrate, high-fiber (HCHF) diet.*

ment in children with type I diabetes. The reasons for the difference in response reported in this study may be attributable to the length of the study, the nature of our fiber supplement, or differences in endogenous insulin release, all of which may influence the outcome.

It is possible that, in our study, the children did not receive sufficient fiber. Because of frequent phone conversation and encouragement by our dietary and nursing staffs, we feel confident that the participants did receive most of the fiber prescribed during the study. However, most of them had difficulty consuming the full amount of fiber-rich foods and would not have tolerated a further increase. It appeared that we were close to their limit as far as the fiber was concerned.

It may be that our study was too short to document improvement, but most of the earlier studies demonstrated changes in glucose control either immediately[1,9] or within the first week of the test diet.[2,8] Although the diet was relatively well received, it is unlikely that the average child with type I diabetes would be willing to follow such a diet over a long time if there were no noticeable early signs of improved diabetic control.

After completion of our study, a 6-wk trial of a HCHF diet in 10 British children was published,[12] which reported a beneficial effect of the diet. The children were similar to our group except that they had better diabetic control while requiring only a single injection of insulin per day. The diets used in the British study were similar to ours, providing 1 g of dietary fiber per 100 cal in the regular diet and 3 g of fiber per 100 cal in the HCHF diet. They also used fresh fruits, vegetables, and grains as the primary source of fiber but added dried beans at breakfast and the afternoon meal.[12] We, on the other hand, used high-fiber crackers as a fiber supplement. Despite reported improvement in glucose control, the English children found the restricted amounts of meat and cheese unacceptable and reverted to a diet midway between the HCHF diet and the regular diet after the trial period.

In the British study there was a significant reduction in pre- and postprandial blood sugar levels and a greater number of hypoglycemic reactions while the children were on the HCHF diet. The mean HbA_{1c} and total insulin dose did not change significantly on the HCHF diet, although three of the children reduced their insulin dose by 6–12 U.[12] Our study failed to show this improvement in glucose control and reduction in insulin requirement. Both at home and in the controlled hospital environment, our patients showed no improvement in basal, preprandial, or postprandial blood glucose levels or in the daily glucose profile. In our study, the degree of diabetic control did not appear to affect the response to the diet; patients with good and poor diabetic control had a similar lack of response. However, the number of patients with well-controlled diabetes (five subjects had $HbA_{1c} < 12\%$) was small and does not warrant broad generalization. Because there was no improvement in glucose control and no higher incidence of hypoglycemic reactions, there was no significant change in insulin dosage.

Perhaps the reason that our patients did not show a positive response to the HCHF diet is that they did not have the capability for endogenous insulin release. Only 1 of our children had significant C-peptide levels while 5 of the 10 British children were C-peptide producers.[12] Three of these five were the only participants to significantly lower their insulin dose on the HCHF diet. It appears likely that a child must still be able to produce a significant amount of endogenous insulin for the HCHF diet to be beneficial.

From this short-term study, we conclude that institution of a HCHF diet does not significantly improve diabetic control in children with long-standing, relatively poorly controlled diabetes. This form of dietary alteration appears to be of limited application in insulin-dependent diabetic patients with very little residual beta-cell function. The effect of such diets on newly diagnosed (or well-controlled) type I diabetic patients requires further study.

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