The Glycemic Effect of Different Meals Approximately Isocaloric and Similar in Protein, Carbohydrate, and Fat Content as Calculated Using the ADA Exchange Lists

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The effect on plasma glucose concentration of four different, approximately isocaloric breakfasts designed using the American Diabetes Association food exchange lists was studied in eight type II diabetic patients. The meals were estimated to contain similar amounts of carbohydrate, protein, and fat and were given in random order. The plasma glucose responses to the different meals were similar except for one meal. This meal resulted in a greater glucose increase but the latter could be explained by the substitution of banana for orange juice in the meal. Banana contains starch as well as fructose and glucose, whereas orange juice contains glucose, fructose, and sucrose. In regard to the postmeal glucose response, these data indicate that the ADA food exchange list is useful in meal planning, at least for breakfast. DIABETES CARE 6: 432–435, SEPTEMBER–OCTOBER 1983.

Food exchange lists have been used in meal planning for diabetic persons for more than 30 yr. The exchange system is based on the assumption that isocaloric diets with similar carbohydrate, protein, and fat compositions, but derived from a variety of different foods, have similar effects on blood glucose. This hypothesis has never been tested using the exchange lists. However, recent work has provided evidence to suggest that it may not be valid.[1–6] The nature of the carbohydrate and the physical form of the food appear to be important determinants of the glycemic effect of different food items ingested.[3,7–9] Because of reports of differing effects on blood glucose responses of various foods, which contain similar amounts of carbohydrate, we elected to study the plasma glucose and serum insulin responses of newly diagnosed adult-onset diabetic persons to four different isocaloric breakfast meals designed using the American Diabetes Association recommended food exchange lists.

METHODS

Eight untreated type II diabetic patients were studied in a metabolic unit. The criteria used for the diagnosis of type II diabetes were those advocated by the National Diabetes Data Group.[10] All were men and were otherwise in good health. Their mean age was 64 ± 3 yr with a range of 52–74 yr. They had a mean body weight of 188 ± 13 pounds (range: 141–250). The percent of desirable body weight was 120 ± 7% (range: 98–159%).[11] They were given four different meals (A, B, C, and D) as breakfast for 4 consecutive days in a random order. Each meal was estimated to contain approximately 500 kcal, 67 g carbohydrate, 21 g protein, and 15 g fat and was designed using the American Diabetes Association (ADA) exchange as follows:

	Meal A	Meal B	Meal C	Meal D
Bread	3	3	3	3
Fat	2	2	2	3
Fruit	1	1	2	2
Milk	1	1	0	0
Medium-fat meat	1	$\frac{1}{2}$	2	2 (lean meat)

After completion of the study, the actual carbohydrate, protein, and fat contents were calculated using Agriculture Handbook #8 of the USDA. The composition of each meal is shown in Table 1.

The subjects signed an informed consent designed according to the Helsinki agreement on human experimentation and the study was approved by the Hospital Committee on Human Subjects. The participants were given a diet consisting of at least 300 g carbohydrate per day for 3 days before testing. During the study they remained on an unrestricted diet containing approximately 250 g carbohydrate daily.

After an overnight fast of 8–10 h an indwelling catheter was inserted into an antecubital vein and kept patent with small amounts of heparin. Blood for glucose and insulin de-

TABLE 1
Composition of the test meals used*

	Meal A		Meal B		Meal C		Meal D	
	120 g orange juice 22 g corn flakes 50 g (1) whole egg 240 g skim milk 50 g white bread 10 g corn oil margarine		70 g banana 44 g corn flakes 15 g peanut butter 240 g 2% milk 25 g white bread		240 g orange juice 15 g bacon 100 g (2) whole eggs 100 g potato 50 g white bread 10 g dietetic jelly		240 g orange juice 165 g (3) griddle cakes 60 g lean ham 45 g dietetic syrup	
	Calculated	Estimated†	Calculated	Estimated	Calculated	Estimated	Calculated	Estimated
CHO (g)	70	67	83	67	69	65	82	65
Protein (g)	22	21	20	18	26	20	29	20
Fat (g)	16	16	13	13	21	21	17	21
Cal	514	496	526	457	574	529	601	529

*Decaffeinated coffee served, if desired.
†Estimated refers to approximate amounts of each constituent determined using the ADA exchange system.

termination was collected at 0745 and 0800 h. At 0800 h the meal was begun and blood was collected every 15 min for 2 h and then every 30 min over the subsequent 2 h. Plasma glucose was determined by a glucose-oxidase method using a Beckman glucose analyzer (Beckman Instruments, Inc., Fullerton, California); serum immunoreactive insulin (IRI) was measured by RIA in duplicate using a kit supplied by Pharmacia Laboratories, Inc. (Piscataway, New Jersey).

The areas under the glucose and insulin curves are presented as means ± SEM and were analyzed using planimetry. Statistical analyses were done using Student's two-tailed t test for paired variates. The criterion of significance was $P < 0.05$.

RESULTS

The plasma glucose concentration increased promptly after each meal. It reached a peak at 60 min (meal A) to 90 min (meal B). By 240 min it had decreased essentially to the pre-meal concentration except for meal B (Figures 1 and 2). The peak glucose rise also was greatest after meal B. It was least after meals A and C. However, none of the differences was statistically significant. The areas under the curves calculated from the baseline values were 207 ± 18 for diet A; 302 ± 36 for diet B; 207 ± 18 for diet C; and 243 ± 24 mg · h/dl for diet D. Thus, the areas were similar for diets A and C and were modestly greater for diets B and D. However, only with diet B did this difference reach statistical significance when compared with diets A and C.

The insulin concentrations also increased rapidly after the meals (Figure 3). The peak insulin concentration was similar after meals A, B, and C and occurred at 90 min after the meal began. The mean peak was higher (110 μU/ml) and occurred later (120 min) after meal D but the differences were not statistically significant. The insulin concentration had not returned to the baseline for any of the meals by 240 min. The areas under the curve were 160 ± 36, 201 ± 59, 172 ± 36, and 225 ± 47 μU · h/dl for meals A, B, C, and D, respectively. In general, the insulin areas correlated with the glucose areas. None of the between-meal insulin differences was statistically significant.

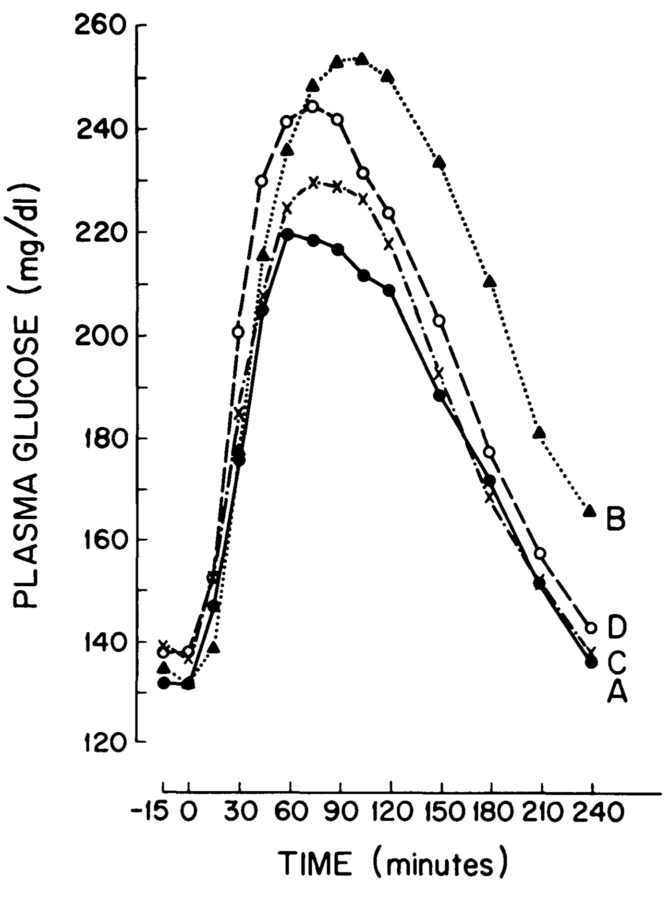

FIG. 1. Plasma glucose response to the four different breakfast meals. Meals were given in random order to the same subjects.

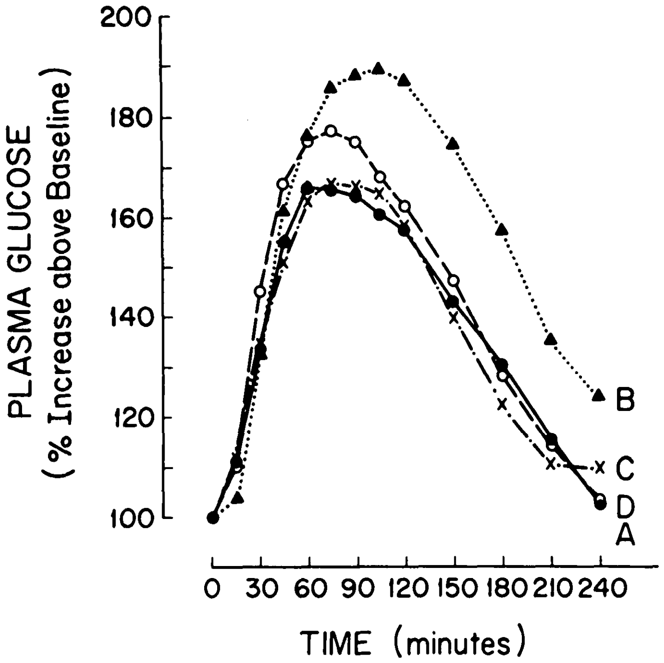

FIG. 2. Plasma glucose rise as a percentage over the fasting value after each of the four diets.

DISCUSSION

Using the ADA food exchange system to calculate breakfast meals containing similar amounts of food energy, carbohydrate, protein, and fat, we were somewhat surprised at the similarity in the plasma glucose curves observed. The mean responses for diets A and C were essentially identical and with diets B and D the response was only modestly greater. When we analyzed the meal contents more closely, however, the similarities and differences could largely be explained. The modestly higher glucose curves observed with meal D could be explained by a 17% greater total carbohydrate content in this meal. In fact, the calculated glucose area above baseline was 19% greater than with meals A or C. Meal B contained only a slightly greater amount of carbohydrate than meal D (83 g) yet the glucose rise was greater. One reason for this may be that in this meal banana was substituted for orange juice as a fruit exchange. In orange juice the carbohydrate is present as approximately equal amounts of fructose, glucose, and sucrose. The carbohydrate in banana also is largely fructose, glucose, and sucrose, but a significant amount of starch also is present unless the banana is very ripe.[12] Fructose ingestion is known to result in lower circulating glucose values than starch.[13] Banana ingestion also has been reported to result in a greater blood glucose rise than orange juice.[4] Indeed, the rise approaches that observed with bread.[4,14] This meal also contained a large amount of corn flakes, which have a high glycemic index.[4]

Our data indicate that use of the exchange system is of value in meal planning of diabetic diets, at least for the foods used commonly for breakfasts, provided the content of starch and the common disaccharides (sucrose and lactose) or their equivalents (glucose + fructose or glucose + galactose, respectively) are considered. Using this information, it is now possible to rationalize the effects of foods on the postmeal glucose concentration. In addition, minor modifications in the exchange system could probably yield a more uniform glucose response.

The major determinant of the blood glucose rise is carbohydrate, and in the American diet, cooked cereal and potato starch is the major carbohydrate ingested. Several investigators have shown that cooked starch is rapidly hydrolyzed to glucose in the intestine and results in blood glucose curves that are similar to those of glucose ingestion per se.[13–16] Its importance in determining the postmeal glucose rise is thus apparent.

When considering the effect of foods on the plasma glucose concentration we would recommend all foods containing a high concentration of cereal starch, such as breads and pastas in the bread exchange list, and the root vegetables, such as potato and parsnips in the high-carbohydrate vegetable exchange list, be considered as a group in meal planning.

Legumes (peas and beans), which also contain a large amount of starch, could be considered as a separate group since they produce a much lower glucose rise in normal individuals[4] and type II diabetic persons (unpublished data). Most likely, the lesser effect of ingested legumes on blood glucose is due to the poor digestibility of the carbohydrate in these foods.[9,17]

Dairy products produce a blood glucose increase which is

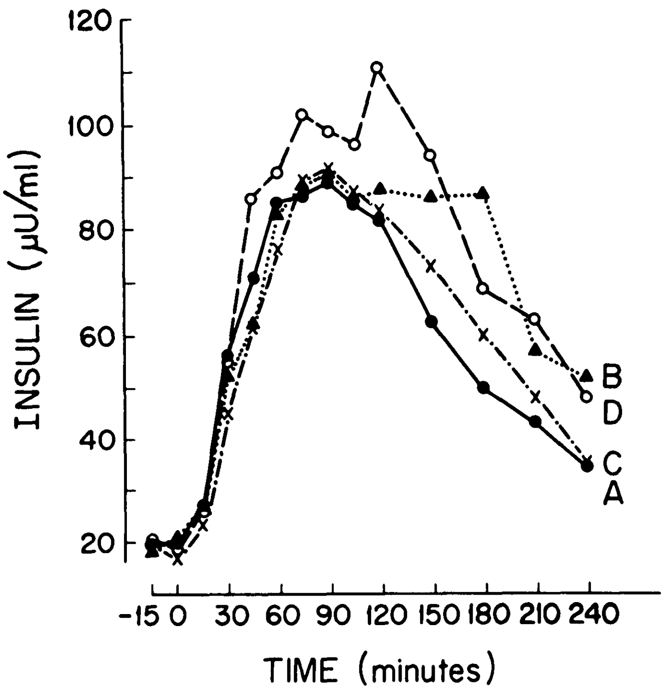

FIG. 3. Plasma insulin response to the four different breakfast meals.

similar to that of legumes. The reduced effect of milk [13](lactose) on blood glucose probably is due to the slow hydrolysis of lactose in the gut[18] and the fact that it is composed of equimolar concentrations of galactose and glucose.

Fruit exchange items in which the carbohydrate generally is a mixture of equal portions of fructose and glucose plus sucrose[12] appear to produce a smaller glucose rise than bread exchange items. However, data regarding their effects on blood glucose are very limited.

Ingested proteins do not appear to significantly increase the blood glucose concentrations in normal individuals or mildly diabetic persons.[14,19] In persons with type II diabetes, large amounts of protein may actually lower the glucose due to stimulation of insulin secretion (unpublished data). Fat may delay gastric emptying[20] and as a result also lower the peak glucose concentration, at least later in the day, but only when given in rather large amounts.[19] Thus, standardization of these food components also should be considered in the overall diet prescription. Nevertheless, the major determinant of the postmeal glucose rise is the carbohydrate content of the meal.

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