Effect of low-glycemic-index dietary advice on dietary quality and food choice in children with type 1 diabetes[1–3]

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ABSTRACT

Background: The practicality of diets with a low glycemic index (GI) is controversial. Theoretically, low-GI diets may limit food choice and increase dietary fat intake, but there is little objective evidence to support such a theory.

Objective: The objective was to determine the effect of low-GI dietary advice on dietary quality and food choice in children with diabetes.

Design: Children aged 8–13 y with type 1 diabetes ($n = 104$) were recruited to a prospective, randomized study comparing the effects of traditional carbohydrate-exchange dietary advice (CHOx) with those of more flexible low-GI dietary advice (LowGI). We determined the effect on long-term macronutrient intake and food choice with the use of 3-d food diaries.

Results: There were no differences in reported macronutrient intakes during any of the recording periods. After 12 mo, intakes of dietary fat (33.5 ± 5.6% and 34.2 ± 6.7% of energy, $P = 0.65$), carbohydrate (48.8 ± 5.4% and 48.6 ± 6.5% of energy, $P = 0.86$), protein (17.6 ± 2.5% and 17.3 ± 3.7% of energy, $P = 0.61$), total sugars, and fiber did not differ significantly between the CHOx and LowGI groups, respectively. The average number of different carbohydrate food choices per day also did not differ significantly. Subjects in the lowest-GI quartile consumed less carbohydrate as potato and white bread, but more carbohydrate as dairy-based foods and whole-grain breads than did subjects in the highest-GI quartile.

Conclusion: Children with diabetes who receive low-GI dietary advice do not report more limited food choices or a diet with worse macronutrient composition than do children who consume a traditional carbohydrate-exchange diet. *Am J Clin Nutr* 2003;77:83–90.

KEY WORDS Type 1 diabetes, children, glycemic index, dietary quality, food variety, fat intake, carbohydrate sources, dietary adherence

INTRODUCTION

Postprandial glycemia is influenced by both the amount and the nature of the carbohydrates in foods. The nature of the carbohydrates is best described by the glycemic index (GI) (1, 2). In equal carbohydrate amounts, low-GI foods such as pasta and dairy products produce less glycemia than do high-GI foods such as bread and potato (3). Several studies showed that low-GI diets improve glycemic control and blood lipid profiles in adults and children with type 1 and type 2 diabetes (4–13). In our recent study of 104 children with type 1 diabetes (14), those who received low-GI dietary advice had significantly better HbA_{1c} concentrations at 12 mo than did those advised to adhere to the traditional measured-carbohydrate diet. Those receiving low-GI dietary advice reported significantly fewer episodes of hyperglycemia, an improved quality of life, and a distinct preference for the low-GI dietary instructions (14).

Despite the scientific evidence and clinical experience supporting the use of low-GI diets, much debate remains about their clinical and practical utility (15). Many argue that it is too soon to put the GI concept into practice because it is difficult to understand and it places yet another, unnecessary burden on people with diabetes (16, 17). It is also claimed that a low-GI diet limits food choice and variety and may also cause a deterioration in dietary quality by increasing the intake of dietary fat and sugar (16, 17). There is little or no objective evidence to support or refute these claims. The American Diabetes Association currently makes no recommendation regarding the use of low-GI foods because it considers the amount of carbohydrate consumed to be of greater effect in good glycemic control (16, 18). Many studies, however, have shown evidence to the contrary (4–14). Many studies in the literature also show that measured-carbohydrate diets are difficult to understand, cumbersome to follow, and poorly adhered to (19–23). Whether low-GI dietary advice might adversely affect dietary quality is not known. The present analysis was designed to address some of the theoretical concerns about the use of low-GI diets. The data were derived from our recent randomized prospective trial from which differences in clinical outcomes were reported previously (14). The current analysis compared the effects of flexible, low-GI dietary advice (LowGI dietary regimen) with those of conventionally measured 15-g carbohydrate-exchange dietary advice (CHOx dietary regimen) on nutritional intake and food choice in children with type 1 diabetes over a 12-mo period.

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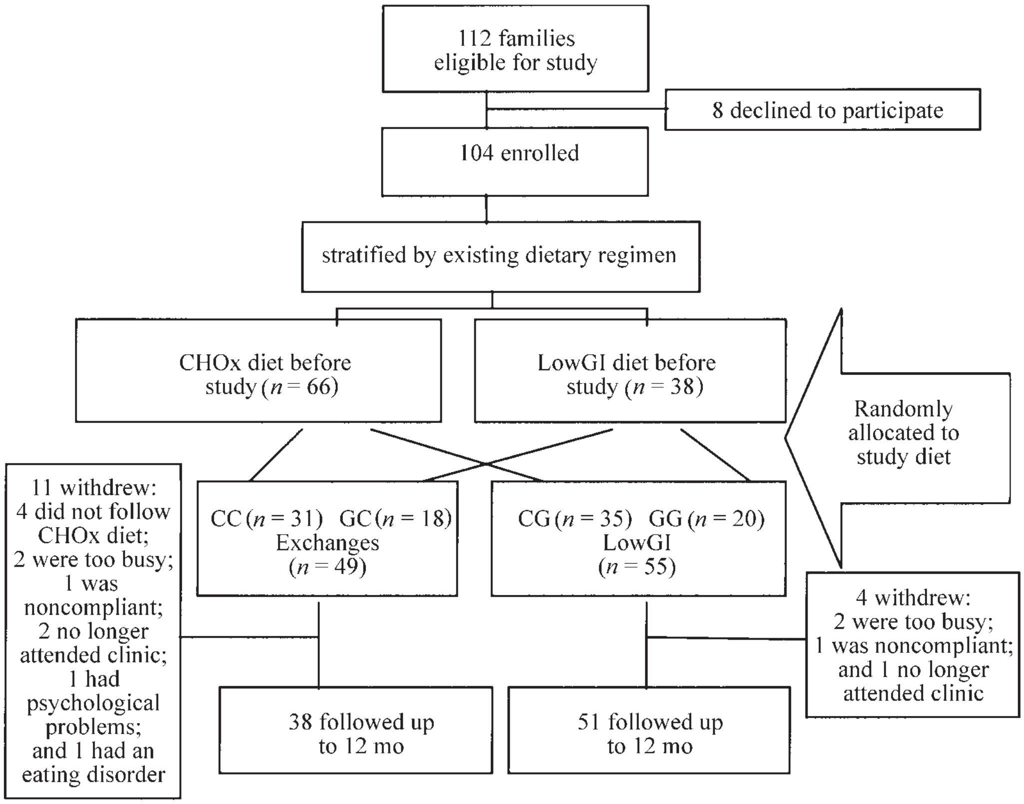

FIGURE 1. Trial design. CC, subjects instructed only in the carbohydrate-exchange (CHOx) diet both before and during the study; GG, subjects instructed only in the low-glycemic-index (LowGI) diet both before and during the study; GC, subjects randomly assigned to the CHOx diet who were consuming the LowGI diet before the study; and CG, subjects randomly assigned to the LowGI diet who were consuming the CHOx diet before the study.

SUBJECTS AND METHODS

Study design

The trial profile used in this study is summarized in **Figure 1**. Children attending the Melbourne Royal Children's Hospital Diabetes Clinic were selected according to the following criteria: *1*) age 8–13 y; *2*) diagnosis of type 1 diabetes for > 1 y; *3*) regular attendance at the clinic (every 3 mo); *4*) no additional dietary restrictions; *5*) no immediate family members with diabetes; *6*) no current medications that would affect appetite; and *7*) immediate family members with ability to read and write English.

Agreement from the primary physician was sought. Of 112 eligible families, 104 agreed to participate. Letters were sent outlining their involvement in the study. Written informed consent was obtained from each child's parent or parents. Subjects were assigned random number codes to ensure patient confidentiality. Approval of the protocol was granted by the Ethics in Human Research Committee of the Royal Children's Hospital.

Diet assessment and education

Individual interviews with the research dietitian were used to collect initial data, instruct the child and parent or parents in the use of food records, and develop a rapport to enhance participation throughout the 12-mo period. Each subject was asked to complete a 3-d food diary at the 1-, 3-, 6-, and 12-mo time points. Two weekdays and one weekend day were specified to account for the variation in food intake at weekends (24). Food diaries were designed to distinguish between the 3 separate meals and 3 snacks. Additional foods consumed before exercise and for treatment of hypoglycemia were also noted. Families were encouraged not to alter their usual pattern of food intake during recording periods. A sample food diary and a contact phone number were provided. Phone calls were made 2 wk before the clinic visits to ensure compliance in completing the food diaries.

At the beginning of the study, subjects were assessed by a dietitian to categorize their existing dietary regimen. This ensured correct stratification of the subjects' prestudy diet (subjects were consuming either the CHOx or LowGI diet) before subjects were randomly assigned either to remain on their current diet or to switch to the alternative regimen. Computer-generated random numbers of 1 (stay on same diet) and 2 (change to alternative diet) were generated in blocks of 10 and assigned consecutively to each subject on recruitment to the study. Of the 104 subjects recruited, 49 were assigned to the CHOx group and 55 to the LowGI group (Figure 1). Education regarding the allocated study diet was then given to the child and parent or parents. Those in the LowGI diet group were instructed to eat regular meals and snacks of carbohydrate-containing foods in their preferred serving sizes to satisfy the appetite, with emphasis on consumption of at least one low-GI food per meal/d and on moderate use of refined sugars and a goal of a low-GI intake of 50–55%. Those in the CHOx group ate a set number of carbohydrate exchanges for each meal and snack, measured in 15-g carbohydrate quantities, and were advised to limit the use of refined sugars; the aim was a GI intake within the expected normal range of 65–70%. Full details of dietary instructions were

TABLE 1
Dietary adherence criteria[1]

Adherence score[2]	Carbohydrate-exchange diet	LowGI diet
1	Correct descriptive measure used Correct quantity must be eaten at all meals or snacks No skipped meals or snacks Appropriate food choices: not candy, chocolates, or soft drinks	Regular meals or snacks based on carbohydrate-containing foods No set quantity necessary No skipped meals or snacks LowGI foods distributed throughout the day with at least one serving/meal per day
2	Diet adhered to but not according to exact measures Correct quantity not eaten at all meals or snacks, but the amount is still appropriate No skipped meals or snacks Appropriate food choices	Diet appropriate as above, but not including sufficient amounts of lowGI foods (ie, less than one serving/meal per day) Distribution of carbohydrate appropriate Sugar-containing foods allowed in combination with other food choices
3	No regard for quantities eaten or for routine (eg, meals or snacks skipped) Inappropriate food choices (eg, soft drinks, candy, or chocolate used as usual exchanges and not eaten in combination with meals)	No regard for quantities eaten or routine (eg, meals or snacks skipped) Inappropriate food choices: selection mainly from top of pyramid, and sweets not eaten in combination with other food choices No inclusion of lowGI foods

[1] LowGI, low-glycemic-index. The exceptions are *1*) food choices used for sports, hypoglycemic treatment, and special occasions; *2*) an extra snack allowed before school between the scheduled breakfast and morning snack (advice given when the morning snack is delayed); *3*) snacks can be split (eg, have two afternoon snacks: one at school and another later); *4*) an additional late-night snack is acceptable if up late at night; *5*) leniency about fruit size for the exchange group; and *6*) for subjects on 4 daily insulin injections *only* (ie, a basal-bolus regimen), it was acceptable to skip morning and afternoon snacks and to eat breakfast late and skip the morning snack if sleeping late.

[2] 1, adhered to diet exactly; 2, slight deviation from recommendations but acceptable for diabetes management; and 3, total noncompliance and unacceptable for diabetes management.

published previously (14). The diet education session was structured similarly for both groups and conducted in an outpatient setting by the same clinical dietitian. A purpose-made flipchart that explained the principles of the diet was used for each of the study diets. Literature was also provided to reinforce the advice (25–27). No other education sessions were planned over the 12-mo period apart from the usual review at clinic visits.

All food diaries were analyzed by the same research dietitian using DIET 3.12 software (Xyris, Highgate Hill, Australia). Portion sizes were estimated against standard portions within the software package according to the household measures recorded. If the food item was not included in the database or if the nutrient profile was incomplete, information from the manufacturer was sought or the most similar food item was substituted. Each subject's intake of energy, protein, fat, fiber, total carbohydrate, total sugars (with inclusion and exclusion of sugars consumed for hypoglycemic treatment or during exercise), and nonmilk extrinsic sugars and the GI and carbohydrate distribution were calculated by use of the food diaries at each review time point. Total carbohydrate referred to the sum of total starch and sugars and did not include dietary fiber. Nonmilk extrinsic sugar content was estimated from the food sources of total sugars, information from the food manufacturer, and food-composition tables (28). Adherence to dietary instruction was also assessed independently by the research assistant at each time point and for every food diary, with the use of specific criteria. Subjects were categorized from 1 to 3: 1, subject adhered exactly to the advice given; 2, subject adhered generally to the advice given and dietary intake was acceptable to diabetes management; or 3, subject did not adhere to the advice given and dietary intake was unacceptable for diabetes management (**Table 1**).

Energy intake was independently assessed as being below, within, or above range. Ranges were based on basal metabolic rate calculations with the use of cutoffs from published sources. The basal metabolic rate was calculated by the use of Schofield's equation (29). The minimum and maximum cutoffs were derived from Goldberg et al (30), by using a value of 0.8 × basal metabolic rate × activity factor, and from Torun et al (31), respectively. Activity levels were individually assessed and defined as light, < 2 organized activities/wk; moderate, 2–5 organized activities/wk; and heavy, > 5 organized activities/wk. The activity factors for these levels were 1.55, 1.75, and 1.95, respectively.

For the purpose of dietary analysis, the daily GI (relative to a standard glucose value of 100) was calculated by summing (grams of carbohydrate from food item/total daily carbohydrate × 100 × GI of food item). GI values were derived from published GI tables (3) and unpublished data from the Human Nutrition Unit, University of Sydney (J Brand-Miller, 1999). Of 284 carbohydrate-containing foods, 194 were assigned a known GI, but 90 were given "estimated" values based on the GI of foods with a similar physical and chemical make-up. Estimations were based on detailed knowledge of the GI database (3) and other factors that affected GI, including the presence of other nutrients, antinutrients, and an acid pH and food processing. An additional exploratory analysis of the GI data was performed at 12 mo, in which the GI data from the entire study cohort were pooled and sorted into GI quartiles; only the subjects in the highest- and lowest-GI quartiles used for further analyses, so that there would be a minimum 10-point difference in GI intake between the subgroups, which previous studies showed to be a clinically significant difference (4, 9). Comparison of dietary quality, food choice, and main sources of carbohydrate foods between the lowest- and highest-GI quartiles was also performed.

Statistical analysis

The sample size of 100 families allowed for a 15% dropout rate and provided 80% power, and the significance level was set at 5% to detect an effect size of 0.625 SD. An intention-to-treat analysis was performed on the assumption that subjects adhered to the dietary advice provided at entry to the study. The food diary

TABLE 2
Demographic data for subjects assigned to the carbohydrate-exchange (CHOx) and low-glycemic-index (LowGI) diet groups[1]

Variable	CHOx (n = 49)	LowGI (n = 55)
Sex (% male)[2]	51	49
Age (y)[3]	10.2 ± 1.6	10.7 ± 1.6
Duration of diabetes (y)[4]	4.0 (1.1, 9.9)	3.4 (1.3, 12.2)
Parents' marital status (% married)[2]	84	89
Socioeconomic status[4,5]		
Father's occupation	4.2 (2.3, 6.5)	4.1 (1.5, 6.6)
Mother's occupation	5.3 (3.6, 6.6)	5.3 (2.3, 6.4)

[1] There were no significant differences between groups.
[2] Significance determined with Pearson's chi-square test.
[3] $\bar{x}$ ± SD. Significance determined with two-sample t test.
[4] Median; range in parentheses. Significance determined with Wilcoxon's rank-sum test.
[5] Daniel's prestige scale: the lower the score, the higher the prestige.

coding and assessment of dietary adherence were performed by the same researcher who was not blinded to the subjects' diet allocation. However, all remaining data analysis and outcome measures were assessed by a separate researcher blinded to the diet allocation.

Results were expressed as means ± SDs unless otherwise stated. Continuous variables were analyzed with the use of a two-sample t test, or multiple linear regression was used to adjust for confounding variables or test for interaction between variables (32). Categorical data were analyzed by using either Pearson's chi-square analysis or Fisher's exact test where appropriate (32). Nonnormal data were analyzed with Wilcoxon's rank-sum test and expressed as medians and ranges (32). For all the GI quartile comparisons, P values were corrected with the use of Bonferroni's correction for multiple comparisons (32). All statistical analysis was performed with STATA 5.0 software (Stata Corporation, College Station, TX) (33).

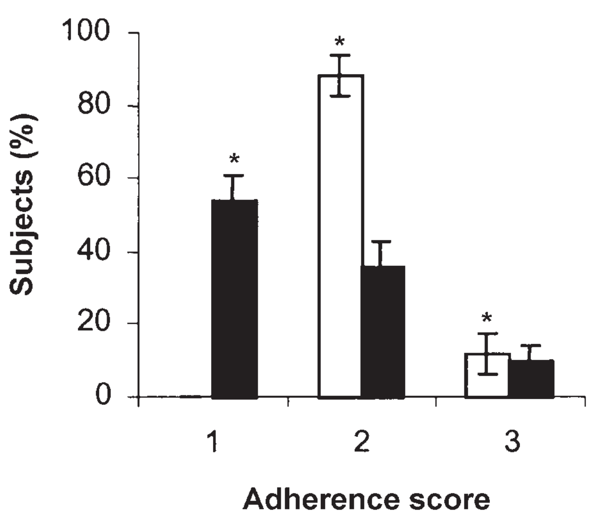

FIGURE 2. Mean (± SEM) adherence scores to dietary instruction in the carbohydrate-exchange (CHOx, □) and low-glycemic-index (LowGI, ■) groups at 12 mo. Adherence scores: 1, subject adhered to diet exactly; 2, subject adhered to diet generally; and 3, subject did not adhere to diet at all (*see* Table 1 for details on specific adherence criteria). *Significantly different from the LowGI group, $P < 0.001$ (Fisher's exact test).

RESULTS

There were no significant differences in demographic data between the 2 study groups (**Table 2**). Fifteen subjects (14%) dropped out during the study period, 11 from the CHOx group and 4 from the LowGI group; the dropout rate from the CHOx group (22%) was significantly higher (P = 0.03) than that from the LowGI group (7%). Apart from dietary assignment, there were no other significant differences at baseline between these subjects.

Of the 89 subjects who completed the study, 4 did not complete a food diary at 6 mo, and 6 did not complete a food diary at 12 mo. The proportion of subjects who recorded intakes less than their habitual intakes by using the cutoffs of Goldberg et al (30) was high in both the CHOx and LowGI groups (respectively, 53% and 43% at 6 mo, P = 0.39; 55% and 46% at 12 mo, P = 0.51). No subjects overreported food intake. The degree of adherence to dietary instruction was significantly different between the 2 dietary groups. At 12 mo, significantly more subjects from the LowGI group than subjects from the CHOx group were categorized with an adherence score of 1 ($P < 0.001$, **Figure 2**). This held true also at all of the earlier time points.

The 2 study groups showed no significant differences in any of the macronutrients measured at the 6- and 12-mo points (**Table 3**). In particular, there were no differences in the intakes of total fat or saturated fat between the 2 study groups. Fiber intake and source also did not differ between the 2 groups; a similar proportion of the fiber intake came from both cereal sources and fruit and vegetable sources. All of the dietary variables were reanalyzed with underreporters excluded, but the data remained essentially unchanged (Table 3). There was no significant interaction between time and treatment group for any of the dietary variables. Despite differences in dietary instruction, there were no reported differences in dietary GI intake between the CHOx and LowGI groups, respectively (57 ± 4 and 55 ± 5 at 12 mo, P = 0.22). However, at all time points, a greater proportion of the subjects in the LowGI group than in the CHOx group were within the lowest-GI quartile of < 55% (14).

There were no significant differences in sugar intake between the groups. Total sugar intake was also analyzed by exclusion of the sugars that were directly used as part of diabetes management (hypoglycemic treatment or preactivity administration), but no differences were apparent. Carbohydrate intake and carbohydrate distribution of meals and snacks throughout the day were not different between the 2 groups (**Table 4**). The exception was the late-night snack, for which subjects from the LowGI group tended to record more carbohydrate intake.

In relation to food variety, the average number of carbohydrate food choices per day was not significantly different between the CHOx and LowGI groups, respectively (11 ± 2 and 11 ± 3 at 6 mo, P = 0.74; 10 ± 3 and 11 ± 2 at 12 mo, P = 0.10). The sources of carbohydrate foods selected by subjects in the lowest- and highest-GI quartiles, assessed as a proportion of the total daily carbohydrate intake, differed significantly. At the 12-mo time point, those in the lowest-GI quartile consumed significantly less carbohydrate as potato and bread (specifically, less white bread) and consumed more carbohydrate as dairy-based foods and whole-grain breads than did the subjects in the highest-GI quartile

TABLE 3
Reported macronutrient intakes in the carbohydrate-exchange (CHOx) and low-glycemic-index (LowGI) groups during the food recording periods over 12 mo[1]

		Full model analysis[2]		Excluding underreporters[3]	
Macronutrient	Time (mo)	CHOx group	LowGI group	CHOx group	LowGI group
Energy (MJ/d)	6	8.2 ± 1.9 [36]	8.5 ± 1.8 [49]	9.2 ± 2.2 [17]	9.3 ± 1.7 [28]
	12	7.9 ± 1.9 [33]	8.5 ± 1.7 [50]	9.1 ± 1.7 [15]	9.3 ± 1.4 [27]
Protein (% of total energy)	6	17.2 ± 2.9 [36]	17.7 ± 3.6 [49]	17.2 ± 3.0 [17]	17.0 ± 3.4 [28]
	12	17.6 ± 2.5 [33]	17.3 ± 3.7 [50]	16.3 ± 1.9 [15]	16.3 ± 4.1 [27]
Fat (% of total energy)	6	34.8 ± 6.2 [36]	34.8 ± 6.9 [49]	35.8 ± 4.8 [17]	35.6 ± 6.4 [28]
	12	33.5 ± 5.6 [33]	34.2 ± 6.7 [50]	35.3 ± 5.4 [15]	36.2 ± 6.3 [27]
Carbohydrate (% of total energy)					
Total	6	47.9 ± 5.7 [36]	47.6 ± 6.8 [49]	46.9 ± 5.2 [17]	47.5 ± 6.4 [28]
	12	48.8 ± 5.4 [33]	48.6 ± 6.5 [50]	48.3 ± 5.2 [15]	47.7 ± 6.2 [27]
Sugars	6	19.2 ± 4.8 [36]	18.5 ± 6.0 [49]	18.8 ± 4.0 [17]	18.9 ± 5.6 [28]
	12	17.7 ± 5.6 [33]	19.5 ± 6.1 [50]	17.3 ± 5.8 [15]	18.8 ± 5.2 [27]
Nonmilk extrinsic sugars	6	6.6 ± 2.9 [36]	6.2 ± 4.5 [49]	6.1 ± 2.4 [17]	6.6 ± 4.6 [28]
	12	6.5 ± 3.8 [33]	7.3 ± 4.7 [50]	6.0 ± 3.0 [15]	7.8 ± 4.9 [27]
Fiber (g/d)	6	21.4 ± 6.4 [36]	22.2 ± 6.6 [49]	23.0 ± 6.7 [17]	22.9 ± 7.1 [28]
	12	20.2 ± 5.0 [33]	22.5 ± 6.5 [50]	22.4 ± 4.1 [15]	23.0 ± 7.2 [27]
Percentage of cereal fiber source (%)	6	52.7 ± 11.9 [36]	54.7 ± 15.2 [49]	53.9 ± 12.1 [17]	57.0 ± 14.6 [28]
	12	57.1 ± 16.3 [33]	52.5 ± 12.5 [50]	56.5 ± 16.4 [15]	51.9 ± 14.1 [27]

[1] $\bar{x}$ ± SD; *n* in brackets. There were no significant differences between groups, no significant time-by-treatment interactions, and no significant main effects of time or treatment.
[2] Includes all subjects assigned to study diet apart from those who withdrew during the study period.
[3] Excludes subjects who underreported usual intake as assessed by cutoffs of Goldberg et al (30).

(**Table 5**). Carbohydrate food sources contributing <5% of total carbohydrate intake were not considered to be clinically significant. Food variety and intake were not different in the lowest- and highest-GI quartiles, but total sugar intake was significantly higher in the lowest-GI quartile (**Figure 3**). The latter was related to higher dairy food consumption in the lowest-GI quartile. The total sugar intake adjusted for differences in dairy food consump-

TABLE 4
Carbohydrate distribution of meals and snacks in the carbohydrate-exchange (CHOx) and low-glycemic-index (LowGI) study groups during the food recording periods for the duration of the study[1]

Time and meal	CHOx group	LowGI group
	g/d	
6 mo		
n	36	49
Breakfast	42 (23–83)	46 (29–99)
Morning snack	25 (7–72)	25 (6–44)
Lunch	51 (28–97)	51 (23–92)
Afternoon snack	27 (12–61)	27 (10–72)
Dinner	60 (35–106)	57 (27–88)
Late-night snack	23 (10–63)	30 (9–104)
Overall	235 (180–379)	243 (133–383)
12 mo		
n	33	50
Breakfast	48 (23–89)	49 (17–91)
Morning snack	25 (15–60)	25 (10–59)
Lunch	47 (16–74)	53 (26–90)
Afternoon snack	25 (15–55)	30 (13–87)
Dinner	56 (27–122)	61 (31–99)
Late-night snack	25 (9–61)	27 (11–94)
Overall	236 (144–361)	244 (142–379)

[1] Median; range in parentheses. Approximate timing of meals or snacks: breakfast, 0800; morning snack, 1100; lunch, 1300; afternoon snack, 1530; dinner, 1830; late-night snack, 2030. There were no significant differences between groups with Wilcoxon's rank-sum test.

TABLE 5
Comparison of carbohydrate food sources between the lowest-glycemic index (GI) (Q1) and highest-GI (Q4) quartiles at 12 mo[1]

Carbohydrate source	Q1 (*n* = 21)	Q4 (*n* = 19)
Glycemic index[2]	50 ± 2	62 ± 2
Total bread (%)	25 (10–45)	35[3] (6–65)
Whole-grain	8 (0–28)	0[3] (0–15)
White	16 (0–30)	32[4] (6–65)
Whole-meal	0 (0–10)	0 (0–30)
Total potato (%)	5 (0–16)	11[4] (0–33)
Ordinary	5 (0–15)	11[4] (0–33)
Sweet potato	0 (0–1)	0 (0–0)
Dairy (%)	12 (3–29)	6[3] (0–18)
Total fruit (%)	18 (7–29)	14 (0–31)
Low-GI varieties	18 (5–29)	12 (0–31)
Other varieties	0 (0–2)	0 (0–5)
Vegetable (%)	2 (0–5)	1 (0–8)
Pasta (%)	7 (0–28)	0 (0–18)
Total rice (%)	0 (0–17)	0 (0–16)
Low-GI varieties	0 (0–17)	0 (0–16)
Other varieties	0 (0–5)	0 (0–9)
Legumes (%)	0 (0–9)	0 (0–2)
Confectionery (%)	1 (0–12)	0 (0–10)
Baked goods (%)	9 (0–19)	6 (0–22)
Crackers (%)	5 (0–18)	4 (0–18)
Breakfast cereals (%)	5 (0–19)	6 (0–29)
Low-GI varieties	0 (0–18)	0 (0–19)
Other varieties	0 (0–19)	5 (0–29)

[1] Median (range) of total carbohydrate intake with *P* value obtained with Wilcoxon's rank-sum test and corrected with Bonferroni's correction for multiple comparisons. Carbohydrate food sources contributing <5% of total carbohydrate intake were considered to be clinically not significant.
[2] $\bar{x}$ ± SD: a minimum 10-point difference in GI intake is regarded as clinically significant.
[3,4] Significantly different from Q1: [3] $P < 0.05$, [4] $P < 0.009$.

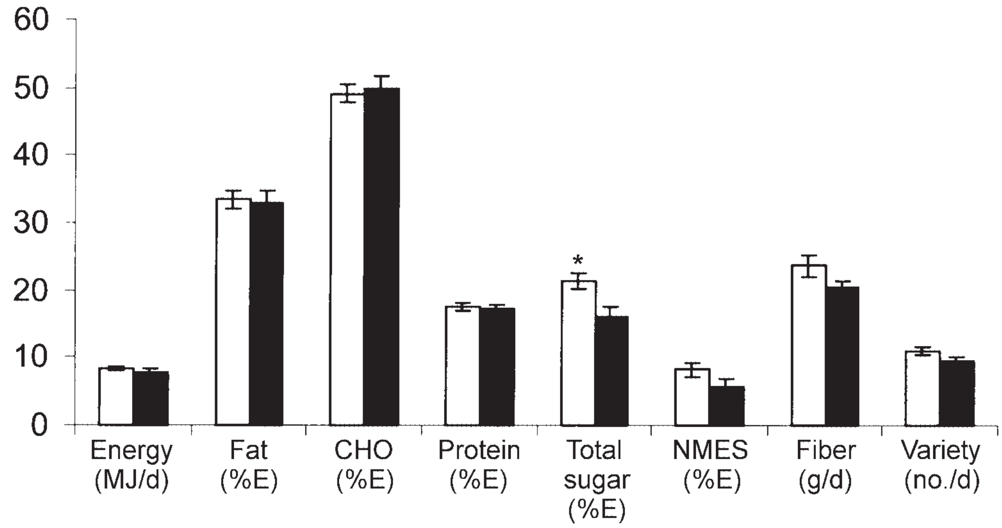

FIGURE 3. Mean (±SEM) macronutrient intakes and food variety in the lowest-glycemic-index (□) and highest-glycemic-index (■) quartiles at 12 mo. CHO, carbohydrate; NMES, nonmilk extrinsic sugars; %E, percentage of total energy. *Significantly different from the highest-glycemic-index quartile, $P = 0.05$ (two-sample t tests with Bonferroni's correction for multiple comparisons).

tion was not different between the lowest-GI and highest-GI quartiles (19.8 ± 6.3% and 17.6 ± 6.3%, respectively; $P = 0.99$ with Bonferroni's correction for multiple comparisons).

DISCUSSION

This study shows that children with type 1 diabetes who were given flexible low-GI dietary advice did not have lower dietary quality or more limited food choices than did children who received more traditional measured-carbohydrate dietary advice. Carbohydrate distribution throughout the day was appropriate for both groups. The dietary records showed that macronutrient, fiber, and energy intakes did not differ significantly between the groups and were comparable to those of children in the general Australian population (34). When the underreporters in this study were excluded, protein intakes were reported to be slightly greater (16.3% and 14.7% of total energy) and carbohydrate intakes slightly less (48.0% and 51.4% of total energy) in the children with diabetes in this study (expressed as the average for the CHOx and LowGI groups at 12 mo) than in children in the general Australian population, respectively (34). This may be a consequence of trying to regulate carbohydrate intake as part of diabetes management. Energy intakes were also comparable with normative data when underreporters in the current study were excluded (average of 9.2 MJ/d in the 2 study groups at 12 mo and of 9.5 MJ/d in the general population) (34). The reported similarity in dietary intake between the 2 study groups is consistent with other studies that compared prescribed and less restricted carbohydrate diets in children with diabetes (19, 23, 35).

There were differences in the main carbohydrate food sources for those in the lowest- and highest-GI quartiles. Subjects in the lowest-GI quartile consumed significantly less carbohydrate as potato and white bread, but ate more carbohydrate as dairy-based foods and whole-grain breads than did subjects in the highest-GI quartile. This pattern is similar to that observed in the northern, western, and eastern European districts in the EURODIAB (European Outpatients with Type 1 Diabetes) study (9) that reported the consumption of carbohydrates as bread, potato, and temperate-climate fruit as the main determinants of GI intake. In our study, a trend to consume more carbohydrate as temperate-climate fruit (specifically apples, oranges, and pears that have a low GI) was also noted in the lowest-GI quartile (Table 5). In our study, dietary fat and refined sugar (nonmilk extrinsic sugars) intake did not differ significantly between the 2 quartile subgroups. However, total sugar intake was significantly higher in the lowest-GI quartile and directly related to the greater consumption of carbohydrates as dairy-based food, which may be specifically related to children's eating habits. Dairy foods were not observed to be a major determinant of GI intake in the adult-based EURODIAB study (9). Food variety tended to be higher in the lowest-GI quartile, but the difference did not reach statistical significance. This finding argues against the suggestion that low-GI advice limits food choice.

Both study groups reported no significant differences in the intakes of total fat and saturated fat. The reported total fat intakes were within the recommended range for this age group of 25–35% of total energy (36) and comparable to the intakes of children in the general Australian population (33% of total energy) (34). However, the saturated fat intake was unacceptably high in both groups when compared with recommendations (36), but it was comparable to that in children in the general population (34). The undesirably high intake of saturated fats in both the CHOx and LowGI groups suggests that greater attention should be given to the sources of fat within the diet. The practical difficulties of modifying a child's total fat and saturated fat intake without detriment to energy and micronutrient intakes have been reported in the literature. Magarey et al (37) showed that it is possible to modify a child's total fat intake, but it is more difficult to reduce the saturated fat component, as that requires the deliberate addition of liberal amounts of polyunsaturated and monounsaturated margarines and oils. Diets low in saturated fats may potentially be low in total energy, too bulky for small appetites, and limited in micronutrients such as calcium if dairy products are targeted for modification. The nutritional implications of reducing the saturated fat content in the diet of the children attending the diabetes clinic would therefore have to be carefully considered.

The poor adherence to dietary instruction by subjects in the CHOx group confirms the findings of earlier studies that evaluated the use of measured-carbohydrate diets in children with diabetes (23, 35, 38). In comparison, subjects in the LowGI group complied well with the dietary advice they had received. The findings in the LowGI group indicate that children are able to regulate their carbohydrate intake and distribute carbohydrate foods appropriately over the course of the day without set limits having to be prescribed. Simple qualitative advice may be just as effective in managing diabetes as a quantified diet, and it would impose less of a perceived burden (19, 23, 35, 38–40).

The limitations of this study must be addressed. Because of the high prevalence of underreporting, the dietary data may be incomplete and unreliable. About half the records indicated energy intakes that were not likely to reflect the child's habitual intake. This criticism plagues all dietary assessment studies (41, 42), especially those conducted in children. Although dietary intake levels can be reliably assessed in adults with the use of 3-d food records (43), that method may not be as reliable in assessing dietary intake in children, particularly with respect to carbohydrate quality and the glycemic index score. More research is required to determine the reliability, repeatability, and validity of the available diet-assessment tools to measure GI intake.

In conclusion, the findings of this large, long-term prospective study provide objective evidence that more flexible dietary instruction with an emphasis on the use of low-GI foods does not result in a deterioration of dietary quality in children with diabetes. Because low-GI dietary advice resulted in improvements in glycemic control as well as the quality of life in these subjects (14), dietary recommendations for the treatment of children with type 1 diabetes may have to be reconsidered in light of our findings.

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