Original Research

Improvement of Dietary Quality with the Aid of a Low Glycemic Index Diet in Asian Patients with Type 2 Diabetes Mellitus

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Key words: type 2 diabetes, Asian, glycemic control, glycemic index, glycemic load, dietary quality, carbohydrate exchanges

Objectives: This randomized controlled study was conducted to determine the effect of low glycemic index (GI) dietary advice on eating patterns and dietary quality in Asian patients with type 2 diabetes (T2DM).

Methods: Asian patients with T2DM (N = 104) were randomized into 2 groups that received either low GI or conventional carbohydrate exchange (CCE) dietary advice for 12 weeks. Nutritional prescriptions were based on the medical nutrition therapy for T2DM, with the difference being in the GI component of the carbohydrates. Dietary intake and food choices were assessed with the use of a 3-day food record.

Results: At week 12, both groups achieved the recommendations for carbohydrate (52 ± 4% and 54 ± 4% of energy) and fat (30 ± 4% and 28 ± 5% of energy) intake. There were no significant differences in the reported macronutrient intake in both groups. With the low GI diet, crude fiber and dietary calcium intake increased, while the dietary GI reduced. Subjects in the lowest dietary glycemic index/glycemic load (GI/GL) quartile consumed more parboiled/basmati rice, pasta, milk/dairy products, fruits, and dough, which are foods from the low GI category. There was a significant reduction in the hemoglobin A_{1c} level at week 12 for patients in the lowest GI/GL quartile ($\Delta = -0.7 \pm 0.1\%$) compared with those in the highest GI/GL quartile ($\Delta = -0.1 \pm 0.2\%$).

Conclusions: These results demonstrate the ability of low GI dietary advice to improve the dietary quality of Asian patients with T2DM.

INTRODUCTION

Excessive rise in postprandial glycemia is associated with increased risk of developing cardiovascular diseases in patients with type 2 diabetes (T2DM) [1]. As a result, it is an important aspect to address in any treatment of diabetes [2]. However, the role of dietary intervention, particularly in modulating dietary carbohydrate metabolism that directly contributes to postprandial hyperglycemia, is still evolving [3,4].

An important paradigm in carbohydrate metabolism and glycemia is the understanding of the relationship between food and the postprandial glycemic effect known as the glycemic index (GI) [5,6]. We recently compared the effects of low GI versus conventional carbohydrate exchange (CCE) dietary advice in Asian patients with T2DM [7]. In that study, the improvement after a low GI diet in glycemic and metabolic controls was small but clinically significant and consistent with results reported in other, Western studies [8,9].

Nevertheless, controversies persist over the practical application of low GI diets and limit their use in routine clinical practice [10]. It is claimed that the GI concept may be misleading as it does not take into account the actual amount of

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Abbreviations: GI = glycemic index, CCE = conventional carbohydrate exchange, MNT = medical nutrition therapy.

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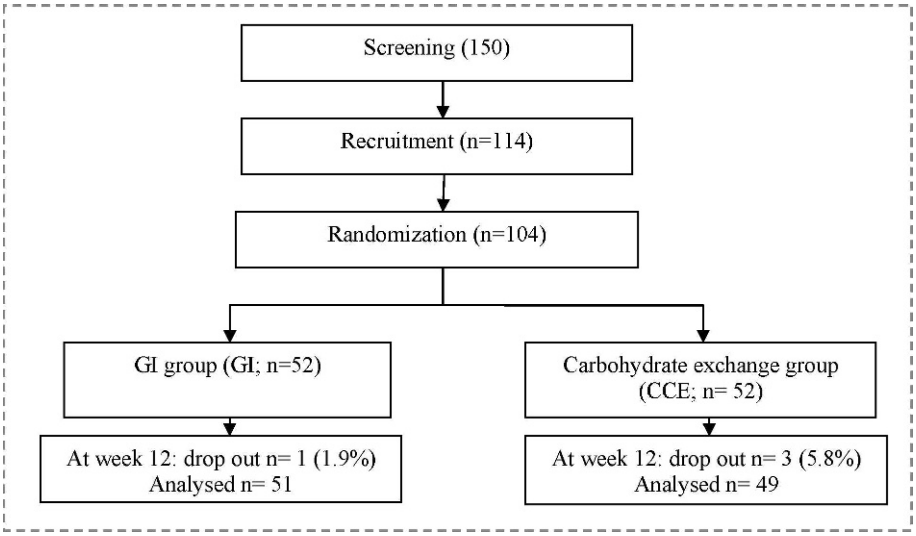

Fig. 1. Subjects at enrollment and follow-up.

food to be consumed; hence, patients might end up over-consuming carbohydrates [11]. Furthermore, some low GI foods, such as chocolate and ice cream, are high in fat and sugar. Thus, one may argue that a low GI diet may affect dietary quality by increasing the intake of dietary sugar and fat [12]. Another concern is that a low GI diet may be difficult for patients to understand and place an unnecessary burden on them, thus compromising their dietary adherence [12]. Further criticism is that the GI values of food are mostly tested in the West and this may differ markedly from their Asian counterparts [13].

Gilbertson and colleagues [14] refuted most of the above claims in their study involving children with type 1 diabetes, but little is known about the effects of low GI diets on dietary quality in Asian patients with T2DM. The purpose of this study was to compare the effects of a low GI diet with those of a CCE diet on nutritional intake and food choice in Asian patients with T2DM over a 3-month period.

MATERIALS AND METHODS

Study Design and Subject Selection

A randomized controlled study was designed to compare the effects of a low GI diet against the CCE diet over a 12-week period in Asian patients with T2DM. The protocol was approved by the Clinical Research and Ethics Committee of our institution and all subjects provided written consent prior to entry into the study.

Eligible subjects were men or nonpregnant women with poorly controlled T2DM (fasting glucose <15 mmol/L and hemoglobin A_{1c} [HbA_{1c}] $<12\%$) who were treated with diet and/or oral antidiabetic agents (metformin <1650 mg/d and/or a first-generation sulfonylurea such as glibenclamide 5–15 mg/d) at a stable dose over the previous 3 months. Subjects were not using insulin or acarbose. None had clinically significant cardiovascular, renal, or liver disease. Detailed inclusion and exclusion criteria were reported elsewhere [7].

A total of 150 potential subjects were screened, of which 114 were eligible. Ten patients were excluded because they did not return for the subsequent visits. The remaining 104 subjects were randomized into 2 study groups by the permuted block randomization method (Fig. 1).

Dietary Intervention

The intervention carried out was in the form of individual dietary counseling, given on a one-to-one basis by a single investigator over the 12-week period. The primary goals of this intervention were to achieve a reduction in hyperglycemia and an improvement in metabolic parameters, as described previously [7]. All subjects were reminded to comply with the respective dietary intervention over the 12-week period. For this purpose, scheduled visits to the lab were arranged, followed by telephone calls to enhance rapport and participation in the study.

Nutritional prescriptions were based on the medical nutrition therapy for T2DM [4] and were prescribed according to patients' individual energy requirements, which were derived from the Quick Method formula as follows: $\text{Energy}_{\text{requirement}} = \text{weight (kg)} \times \text{quick method factor}$ [4]. Values of the Quick Method factor were determined based on the subject's body mass index and physical activity level.

Dietary advice was similarly structured for both groups and the only difference was primarily in the carbohydrate component (GI) of the diet. The aim was for the diet to be high in carbohydrate (50–60% of energy) with either a low or

Table 1. List of Key Foods Provided to the Subjects in the GI Group

Food Groups	Food Products, Low GI
Rice	Basmati and parboiled
Noodles	Pasta and noodles (wheat noodles)
Breads	Whole grain bread
Tubers	Sweet potatoes
Legumes	All legume products
Fruits	Temperate fruits
Milk and dairy products	All milk, especially low-fat milk

high GI food emphasis, depending on the treatment's allocation. Dietary instructions for the GI and CCE groups were adapted from those of Gilbertson and colleagues [14], with a few modifications to suit the local context.

In the GI group, a ''this-for-that'' approach [15] was used to advise subjects to eat low GI carbohydrate foods, at least 1 low GI food in each meal to achieve a goal of a daily calculated dietary GI of <55 and a total carbohydrate intake of at least 50–55% of total energy. Subjects were advised to spread ingestion of the carbohydrate-containing foods evenly throughout the day. The amount of carbohydrate food consumed was based on standard household measurements [16] and was set according to the subject's requirements. The volumes for common utensils used in the household measure description included spoons (1 teaspoon = 5 ml; 1 tablespoon = 15 ml), bowls (1 medium bowl = 250 ml), and cups (1 cups = 150 ml). The food servings were explained to the subjects as correct (100% portion), too big (serving size was increased to 150% of the correct portion), or too small (serving size was 50% less than the correct portion), depending on their energy requirements. These cut points were based on the study that measured relative increment of portion size and energy intake [17].

The availability of low GI local Malaysian foods and food products is very limited [13]. As a result, subjects were encouraged to strictly consume the key carbohydrate foods with known low GI values (Table 1), with sample menus provided to them.

Subjects in the CCE group were instructed to eat a set number of exchanges from each of the food groups for each meal, with emphasis on carbohydrate quantity, without referring to the GI concept and deliberate recommendation of high GI food types. In this exchange system, 1 exchange of carbohydrate equals 15 g of carbohydrate [4]. Subjects were allowed to exchange or trade food within a food group with the assumption that it was similar in nutrient content and the manner by which it would affect the subject's blood glucose level. They were also advised to spread the carbohydrate exchanges evenly throughout the day [4]. The exchange list and sample menu were also provided to the subjects.

Dietary Assessment

Subjects were asked to record all foods and beverages consumed in a 24-hour period over 3 consecutive days at baseline (used as the basis for individualized dietary advice), and at 4 and 12 weeks after randomization. Two weekdays and 1 weekend day were specified in the record to account for the variation in food intake during weekends.

The food records were returned at each visit. Phone calls were made 2 weeks prior to each visit to ensure compliance in completion of the records. Food records were rechecked with the subjects before being analyzed for discrepancies and omissions, including food preparation, cooking method, food brand name, portion size, and ingredients, to ensure accuracy and improve validity.

Nutrient analysis was performed using a computerized dietary analysis program (Nutritionist Pro Version 2.0; First Data Bank, The Hearst Corp., New York). The results were presented as mean daily intake of energy, protein, total carbohydrate, fat, cholesterol, fiber, sodium, and calcium, as well as dietary GI and GL. In this analysis, total carbohydrate referred to the sum of total starch excluding fiber. The crude fiber content was listed in the Malaysian Food Composition Table [16]; therefore, the total fiber content calculated from the dietary record analyses was reported as crude fiber. In addition to the above, subanalysis was performed to determine the carbohydrate distribution of meals and snacks throughout the day.

The daily dietary GI and GL were calculated from the 3-day food records at each point in time according to the specified formula [6,13]. The GI values were derived from the local available data that had either been published [13,18–21] or obtained through email communications with the respective authors. However, data on local food products were very limited; therefore, GI values of those in the International Table [21] and/or updated database at the GI website [22] were extensively used.

When more than one GI value was available for a particular food, a mean GI value was used. However, if the GI value was not available, estimated values were used based on the GI of foods with similar matched factors such as the type of fiber (soluble or insoluble), fat content, acidity, particle size, protein, and cooking and processing methods [6]. If the GI value of food was unknown and the value of a suitably similar food could not be estimated, the food was excluded from the analysis. For the purpose of quality control in calculating the dietary GI, food records that contained more than 20% of the estimated values were excluded from the data set.

The dietary GI data from all subjects were pooled and divided into quartiles. An additional analysis was performed to compare food choices and main sources of carbohydrate foods between the lowest and highest GI quartiles. For that purpose, carbohydrate-containing foods were divided into 14 subgroups in order to identify specific sources of carbohydrate that contributed to the GI value of the study subjects. These subgroups included rice, bread, noodles/pasta, local cakes (*kuih-muih*), dough, starch vegetables, fruits, biscuits, breakfast cereal, legume, milk/dairy products, condensed milk, sucrose added to beverages, and miscellaneous. This classification of the foods was made on a practical rather than a scientific basis to suit the local perspective. Each carbohydrate food group was further divided on the basis of either low or high GI values.

Adherence to dietary instruction was assessed and categorized by the investigator at each visit and, similarly, the validity of the food records was scrutinized with the use of specific criteria [14]: category 1 was for subjects who adhered closely to the advice given (good); category 2 was for subjects who adhered generally to the advice given and dietary intake was acceptable to diabetes management (medium); and category 3 was for subjects who did not adhere to the advice and dietary intake was unacceptable for diabetes management (poor).

Statistical Analysis

The sample size (N = 104) allowed for a 15% dropout rate based on a previous low GI study [14] and provided 80% power to obtain a statistically significant ($\alpha = 0.05$) change in HbA_{1c} of 0.6% between the 2 groups over 12 weeks.

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) software (SPSS version 11.5 Inc., Chicago, IL) and the significance level used for all tests was set at $p < 0.05$. An intention-to-treat analysis was performed on the assumption that subjects adhered to the advice given at entry into the study and had available baseline and endpoint values of HbA_{1c}. Results were expressed as mean ± SD, unless otherwise stated.

Comparison between groups for dietary intake and knowledge status was made by split-plot analysis of variance (SPANOVA), using the general linear model repeated-measure procedure. These procedures were used to test time, group, and time*group interaction over time. A *t* test or 1-way analysis of variance (ANOVA) was performed to compare changes between 2 and more groups where appropriate. Categorical data were analyzed using Pearson's χ^2 analysis. Non-normal data were analyzed with the Mann–Whitney test and results were expressed as medians and ranges.

RESULTS

At week 12, 100 subjects completed the study, yielding a total drop-out rate of 3.8% (GI = 1.9%; CCE = 5.8%), with no significant differences between the 2 groups (Fig. 1). There were no significant differences in demographic data between the groups at baseline (Table 2). The 3 main ethnic groups in the country were each well represented, with the Malays making up 53%, followed by Chinese (24%) and Indians (22%). All baseline dietary data were comparable except that the GI group had significantly higher crude fiber intake ($p < 0.001$) than the CCE group (Table 3) did.

All subjects (N = 100) completed the 3-day food records at each visit. There were no significant associations between the adherence rate and the advice given (Fig. 2). At week 12, the majority of the subjects from both groups (GI = 76.5%; CCE = 69.4%) reported good to medium adherence to the advice given (categories 1 and 2).

Table 2. Demographic and Socioeconomic Background of the Subjects in the GI and CCE Groups at Baseline

	GI (n = 51)		CCE (n = 49)	
Age (years)	57.6 ± 8.6		55.2 ± 11.1	
Duration of Diabetes (years)	6.3 ± 4.4		6.4 ± 5.5	
Characteristics	n	% of Subjects	n	% of Subjects
Sex				
Male	19	37.3	18	36.7
Female	32	62.7	31	63.3
Ethnicity				
Malay	27	52.9	26	53.1
Chinese	12	23.5	18	36.7
Indian	11	21.6	4	8.2
Others	1	2.0	1	2.0
Marital status				
Single	3	5.9	5	10.2
Presently married	40	78.4	34	69.4
Widowed/divorced	8	15.7	10	20.4
Education level (% of subjects)				
No formal education	4	7.8	6	12.2
Primary school	15	29.4	16	32.7
Secondary school	21	41.2	18	36.7
Tertiary	11	21.6	9	18.4
Employment status*				
Professional	3	5.9	3	6.1
Semiprofessional	5	9.8	3	6.1
Nonprofessional skilled-worker	7	13.7	1	2.0
Nonprofessional non-skilled-worker	5	9.8	9	18.4
Pensioner	14	27.5	14	28.6
Housewife	7	33.3	19	38.8
Monthly household income†				
Less than RM 2000	26	51.0	32	65.3
RM 2001–RM 5000	17	33.4	13	26.5
Above RM 5000	8	15.7	4	8.2

* Based on Abramson JH, Abramson ZH: ''Survey Methods in Community Medicine,'' 5th ed. Edinburgh: Churchill Livingstone, 1999.

† Based on average monthly gross income at urban area (Anon 2006).

Table 3. Nutrient Intake Data (mean ± SD) Calculated from Three-Day Food Records of the Subjects in the GI and CCE Groups over 12 Weeks[1]

	GI Group (n = 51)			CCE Group (n = 49)			*p* Value[2]		
Nutrient	Baseline	Week 4	Week 12	Baseline	Week 4	Week 12	Group	Time	Time × Group
Energy (kcal)	1632 ± 314	1479 ± 312	1512 ± 325	1686 ± 382	1567 ± 361	1526 ± 328	NS	<0.001	NS
EI/BMR	1.2 ± 0.2	1.1 ± 0.2	1.1 ± 0.2	1.2 ± 0.3	1.1 ± 0.2	1.1 ± 0.2	NS	<0.001	NS
Protein									
Gram	69 ± 15	71 ± 16	70 ± 15	67 ± 15	68 ± 15	66 ± 15	NS	NS	NS
% energy	17 ± 3	19 ± 3	18 ± 3	16 ± 3	18 ± 3	17 ± 3	NS	NS	NS
Carbohydrate									
Gram	222 ± 44	198 ± 42	200 ± 46	236 ± 56	214 ± 57	207 ± 48	NS	<0.001	NS
% energy	55 ± 4	54 ± 5	$52 \pm 4^{3*}$	57 ± 4	53 ± 4	54 ± 4	<0.05	NS	NS
Fat									
Gram	51 ± 14	48 ± 13	51 ± 13	51 ± 14	48 ± 13	51 ± 21	NS	NS	NS
% energy	28 ± 4	29 ± 4	30 ± 4	27 ± 4	28 ± 4	28 ± 5	NS	NS	NS
Cholesterol (mg)	$246 \pm 80^{a,b}$	$226 \pm 85^{a**}$	$222 \pm 77^{b**}$	$252 \pm 61^{a,b}$	$234 \pm 60^{a***}$	$223 \pm 64^{b***}$	NS	NS	NS
Crude fiber (g)	$13 \pm 6^{***a,b}$	$26 \pm 10^{***,a***}$	$24 \pm 1^{***,b***}$	$9 \pm 4^{a,b}$	$11 \pm 4^{a***}$	$11 \pm 5^{b***}$	<0.001	NS	NS
Calcium (mg)	$664 \pm 333^{a,b}$	$795 \pm 286^{*,a**}$	$781 \pm 314^{**,b**}$	$588 \pm 305^{a*}$	$662 \pm 283^{a,b}$	$610 \pm 285^{b*}$	<0.01	<0.05	NS
Sodium (mg)	2185 ± 728	2085 ± 729	2104 ± 812	2086 ± 930	2028 ± 702	2169 ± 907	NS	NS	NS
Dietary glycemic index†	$63 \pm 5^{a,b}$	$53 \pm 7^{***,a***}$	$57 \pm 6^{***,b***}$	64 ± 6	64 ± 5	64 ± 5	<0.001	<0.05	<0.001
Dietary glycemic load†	$139 \pm 30^{a,b}$	$106 \pm 25^{***,a***}$	$108 \pm 32^{**,a***}$	$152 \pm 40^{a,b}$	$135 \pm 37^{a***}$	$131 \pm 30^{a***}$	<0.001	NS	NS

[1] Two-way repeated measures ANOVA, with the baseline value as covariate.

[2] Significant differences from the CCE group.

[a,b] Means in a row with like superscript letters are significantly different from baseline within the group.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

† n = 88, excluded food records with >20% estimated GI values.

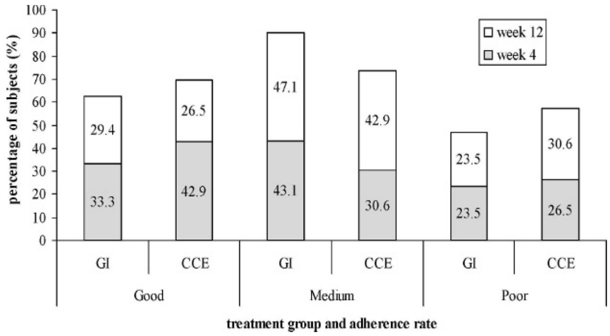

Fig. 2. Adherence score of the subjects to dietary advice in the GI and CCE groups at week 4 and week 12. No significant association between treatment groups and adherence score (χ^2 correlation test, $p > 0.05$). Adherence score: 1, good adherence; 2, medium adherence; and 3, poor adherence (see Table 3 for details on specific adherence criteria).

There was a significant decrease in energy intake with time ($p < 0.001$), but no significant differences between groups were observed (Table 3). The mean (± SD) energy intake to basal metabolic rate (EI/BMR) ratio for the 3-day food records of all the combined subjects, regardless of the treatment groups, were 1.21 (0.25), 1.10 (0.23), and 1.10 (0.22) at baseline, week 4, and week 12, respectively, which was below the acceptable cut-off value set by Goldberg and colleagues [23]. Prevalence of underreporting was similarly high in both groups at all time points. When subjects who underreported in this study were excluded from the analysis, energy intake and macronutrients increased significantly ($p < 0.001$), but these increases did not differ significantly between the groups (mean [kcals] ± SD, GI: 1847 ± 305; CCE: 1847 ± 305).

Reported intake of protein, fat, and carbohydrate remained reasonably consistent between the 2 study groups over the 12-week study (Table 3), with no significant differences noted between the study groups. However, when expressed as a percentage of energy, the GI group had a significantly lower carbohydrate percentage (GI: 53% vs CCE: 55%, $p < 0.05$) than the CCE group, even after an adjustment for the baseline values (Table 3).

Overall, subjects had comparable intake of dietary carbohydrate and carbohydrate distributions were similar at all mealtimes at baseline (Table 4). The exception was breakfast, with subjects from the low GI group recording less carbohydrate intake. This pattern continued throughout the study period, with subjects in the low GI group having significantly lower carbohydrate intake at breakfast than subjects in the CCE group ($p < 0.05$). However, no difference between groups was observed for the remaining meals throughout the study.

Crude fiber increased over time in both groups ($p < 0.001$) and subjects in the GI group had a significantly higher consumption of crude fiber than subjects in the CCE group did

Table 4. Carbohydrate Intake and Distribution throughout the Days in the GI and CCE Groups over a 12-Week Period[1]

	GI (n = 44)		CCE (n = 44)	
Meal[2]	Median	Range (g/d)	Median	Range (g/d)
Baseline (week 0)				
Breakfast	39.8*	31.1–139.1	49.2	28.2–94.1
Morning tea	43.8	0–53.2	45.2	0–49.9
Lunch	45.0	20.7–114.0	44.0	8.4–140.9
Tea time	43.9	0–65.5	45.1	0–73.7
Dinner	41.4	22.6–111.6	47.6	33.6–123.8
Supper	44.6	0–41.4	44.3	0–54.0
Overall	215.1	145.2–351.2	239.2	125.8–371.8
Week 4				
Breakfast	38.1*	19.8–88.2	50.9	16.1–105.0
Morning tea	45.5	0–59.2	43.5	0–54.7
Lunch	44.8	17.9–105.7	44.2	16.0–98.1
Tea time	43.3	0–73.6	45.7	0–70.0
Dinner	41.4	19.1–88.6	47.6	19.5–104.7
Supper	44.6	0–50.0	44.5	0–56.8
Overall	193.7	127.4–324.6	191.8	142.6–337.6
Week 12				
Breakfast	37.7*	15.9–86.0	51.3	12.4–118.7
Morning tea	44.1	0–43.1	44.9	0–43.3
Lunch	48.0	27.2–114.4	41.0	0–135.0
Tea time	46.2	0–76.7	42.9	0–53.7
Dinner	40.4	24.6–100.6	48.7	18.1–100.0
Supper	43.7	0–52.8	45.3	0–60.0
Overall	196.8	102.8–301.9	193.2	136.1–323.3

[1] Median and range in parentheses.
[2] Approximate timing of meals or snacks: breakfast, 0730; morning tea, 1030; lunch; 1330; afternoon snack, 1630; dinner, 2030; supper, 2230.
* Significant differences from the CCE group with the Mann–Whitney test, $p < 0.05$.

($p < 0.001$; Table 3). The differences between groups remained significant even after adjustment for the baseline values ($p < 0.001$). A detailed examination of the sources of crude fiber found that 50% of the crude fiber intake was from cereal sources such as rice, bread, and noodles. This proportion was comparable in both groups at baseline. There were no significant differences in micronutrient intake between the 2 groups. The exception was for dietary calcium, whereby the GI group had consumed greater levels of calcium than the CCE group had ($p < 0.05$; Table 3).

For the purpose of calculating dietary GI, 12 subjects' food records (GI = 7; CCE = 5) were excluded from the analysis because more than 20% of the carbohydrate foods had to be estimated for their GI values. In total, 216 carbohydrate-containing foods were identified from the 264 food records; 12% (25 foods) of those contained little or no carbohydrate. Of 191 carbohydrate foods, 134 (70.2%) were obtained from known sources [21] and 31 (16.2%) were substituted for the nearest comparable foods based on their similar physical and chemical make-up. However, the GI values of 26 (13.6%)

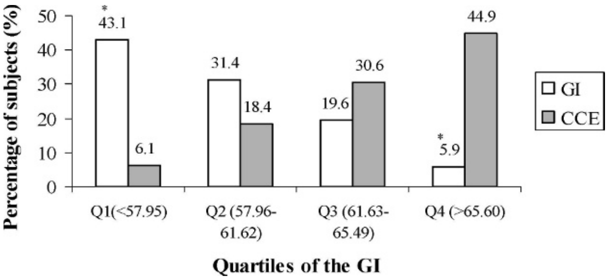

Fig. 3. Percentage of subjects based on the quartiles of the GI at week 12 in the GI and CCE groups. * Significantly different from the CCE group between quartiles 1 and 4 with Fisher's exact test, $p < 0.001$.

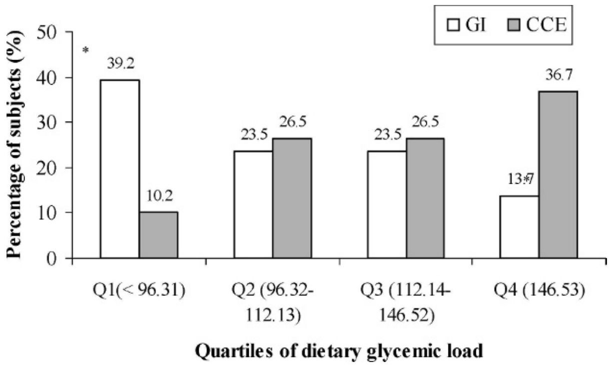

Fig. 4. Percentage of subjects based on the quartiles of the glycemic load at week 12 in the GI and CCE groups. * Significantly different from the CCE group between quartiles 1 and 4 with Fisher's exact test, $p < 0.01$.

foods could not be identified, and thus were excluded from the analysis.

There was no significant difference in terms of dietary GI and GL intake between the 2 groups at baseline (Table 3). At week 12, the GI group had significantly lower dietary GI than the CCE group did ($p < 0.001$). There was a significant effect of time*group interaction ($p < 0.001$), with the GI group reaching a significant reduction of 10 units at week 4 and 6 units at week 12 ($p < 0.001$) while these remained unchanged in the CCE group. Calculated dietary GI was positively correlated with dietary GL ($p < 0.001$; r = 0.49) in a bivariate analysis. The diet GL was also significantly lower in the GI than the CCE group ($p < 0.001$), but no significant effect of time and time*group interaction was observed (Table 3).

Subjects were divided into 4 quartiles according to the dietary GI and GL to identify the number of subjects from both groups in each quartile (Figs. 3 and 4). The proportion of subjects in the lowest and highest GI quartile between the GI and CCE groups was statistically significant ($p < 0.001$). The majority of the subjects from the GI group were in the lowest quartile of dietary GI/GL and this pattern was *vice versa* for those in the highest quartiles. This difference between the lowest and highest quartiles was statistically significant ($p <$ 0.001).

Although the changes in HbA_{1c} from baseline to week 12 did not differ significantly between the 2 groups, as reported previously [7], there was a positive significant association between dietary GI ($p < 0.05$; r = 0.03) and GL ($p < 0.01$; r = 0.28) and the changes in HbA_{1c} levels at the end of week 12. However, no significant relationships between total carbohydrate intake and the improvement in glycemic control were observed in this study ($p = 0.108$; r = 0.126).

One-way ANOVA was performed to compare the changes in HbA_{1c} level from baseline across the quartile of GI. There was a larger reduction in HbA_{1c} level at week 12 for patients in the lowest GI/GL quartile than in those in the highest GI/GL quartile ($p < 0.05$). The sources of carbohydrate foods selected by subjects in the lowest and highest GI quartiles were assessed as a proportion of each serving of carbohydrate to the total daily carbohydrate intake (Table 5). At week 12, there were differences in the main carbohydrate food sources for subjects in the lowest and highest GI quartiles. Patients in the lowest GI quartile consumed significantly more carbohydrate in the form of rice (parboiled and basmati), bread (whole grain), pasta, temperate-climate fruits (such as apples, oranges, and pears), and biscuits, especially from the low GI varieties, as well as milk and dairy products, than did the subjects in the highest GI quartile ($p < 0.05$).

On the other hand, patients in the highest quartile consumed significantly more rice (white and glutinous), bread (wholemeal), starchy vegetables (potato and yam), condensed milk, dough (*roti canai*), and miscellaneous food products (jam, sushi) from the high GI varieties ($p < 0.05$). Intake of *kuih*, breakfast cereal, beverages, confectionery, legume, and sucrose in drinks did not differ significantly between the groups. However, patients in the lowest quartile tended to have a higher consumption of confectionery and legumes compared to those in the highest quartile of the dietary GI.

DISCUSSION

This study showed that patients with T2DM who were given a low GI diet did not differ significantly in energy and macronutrient intake or have limited food choices as compared to those following conventional dietary advice. Both the GI and CCE groups achieved the recommendations for carbohydrate (52% ± 4% and 54% ± 4% of energy) and fats (30% ± 4% and 28% ± 5% of energy), respectively, which were within the range of recommendations of the Malaysian Dietitians' Association 2005 guidelines [4]. Dietary fat intake was also comparable in both groups, thus disputing the claim that low GI diets might cause deterioration in dietary quality by increasing dietary fats [12].

Low GI diets have been shown to benefit body weight control by inducing higher satiety and hence less energy intake

Table 5. Comparison of Carbohydrate Sources between the Lowest GI (Q1) and Highest GI (Q4) Quartiles at Week 12

	Q1 (n = 25)[1]		Q4 (n = 25)[1]	
Glycemic Index (Mean ± SD)	58 ± 8		66 ± 6	
Carbohydrate Sources	Median	Range	Median	Range
Total rice (%)	20	0–57	41**	21–79
Low GI varieties (%)	12	0–57	0**	0–0
High GI varieties (%)	0	0–25	41**	21–79
Total bread (%)	12	3–32	11	0–26
Whole grain (%)	12	3–32	0**	0
Wholemeal (%)	0	0–3	11**	0–27
White bread (%)	0	0–6	0	0–10
Total noodle and pasta (%)	7	0–45	7	0–27
Noodle wheat based (%)	0	0–26	0	0–15
Noodle rice based (%)	0	0–26	6	0
Pasta (%)	0	0–19	0*	0
Total local cakes (Kuih (%))	0	0–26	3	0–12
Local cakes, wheat based (%)	0	0–26	0	0–12
Local cakes, rice based (%)	0	0–6	0	0–3
Total dough (%)	0	0–29	0	0–14
Low GI varieties (%)	0	0–29	0*	0
Other varieties (%)	0	0	0*	0–14
Starch vegetable (%)	2	0–10	2	0–10
Low GI varieties (%)	1	0–10	1	0–5
Other varieties (%)	0	0–5	1*	0–9
Total fruits (%)	10	5–24	4**	0–16
Low GI fruit (%)	8	0–22	1**	0–10
Other varieties (%)	3	0–11	2	0–11
Milk and dairy products (%)	9	0–30	0**	0–16
Condensed milk (%)	0	0–5	0*	0–22
Biscuits	4	0–22	0	0–12
Low GI varieties	0	0–22	0*	0–11
Other varieties	0	0–12	0	0–12
Beverages	2	0–20	4	0–16
Low GI varieties	2	0–18	2	0–16
Other varieties	0	0–5	0	0–5
Breakfast cereal	0	0–13	0	0–7
Low GI varieties	0	0–11	0	0–4
Other varieties	0	0–2	0	0–5
Miscellaneous	2	0–9	3	0–13
Low GI varieties	2	0–9	1	0–4
Other varieties	0	0–4	1*	0–13
Confectionary	0	0–21	0	0–10
Legume	0	0–10	0	0–2
Sucrose added	2	0–12	3	0–14

[1] Median (range) of total carbohydrate intake, with p value obtained by using Mann–Whitney test. Carbohydrate food sources contributing <5% of total carbohydrate intake were considered to be clinically nonsignificant.
* $p < 0.05$, ** $p < 0.001$, significantly different from Q1.

ad libitum at subsequent meals compared to high GI meals [24]. However, the current study reported a comparable energy intake deficit of 7.2% and 7.6% in the GI and CCE groups, respectively, which does not support this finding. It is likely that a failure to detect significant differences in dietary intake in these data might be attributed to the high prevalence of food record underreporting.

Similarity in the amount of carbohydrate consumed and its distribution over the day in both the GI and CCE groups indicated that patients were able to regulate the amount of carbohydrate appropriately throughout the day without having to resort to prescribed exchanges. Nevertheless, the low intake of carbohydrate during breakfast could be attributed to the whole grain bread recommended for subjects in the GI group. This was the only available low GI bread in the market, which happened to have a higher content of protein and fiber than the ordinary whole meal bread [19].

Subjects in the low GI group were able to further increase the amount of crude fiber consumed than were those in the CCE group. This was due to an increase in consumption of cereal fiber, whole grain bread, basmati rice, biscuits, and fruits, especially from the low GI varieties. An attempt was made to keep the intake of crude fiber constant in both groups, but this was not possible because of the patients' individual food preferences and the fact that low GI foods tend to be higher in fiber. Increased fiber intake is considered favorable, as it brings the fiber level closer to the recommended levels [4].

The mechanism by which dietary fiber exerts its beneficial effect on glycemic control may be somewhat similar with a low GI food: by slowing the rate of carbohydrate absorption [25]. It is thus impossible to separate the effect of fiber alone from that of low GI foods and it would seem inappropriate to dismiss the usefulness of low GI foods in the management of T2DM in favor of dietary fiber. The most important message emerging from this and previous studies is that the combination of low GI carbohydrates, which are also rich in soluble fiber, provides the greatest benefit to patients with diabetes [26,27].

A reduction of dietary GI by 10 units is considered clinically significant and has been shown to exert a positive effect on glycemic outcomes [8]. In this study, glycemic improvement could be observed as early as week 4, in which the mean fructosamine level reduced significantly in the GI group compared to the CCE group, as reported previously [7]. It is acknowledged that there was difficulty in maintaining a low GI diet over long periods, which is a factor that compromises all diet-related studies, including the current one. At week 12, a reduction of only 6 units in the GI value in the GI group was smaller than that reported in other studies [28,29]. This might have contributed to the insignificant effect on HbA_{1c} at 12 weeks.

The significant changes in glycemic control obtained by Rizkalla and colleagues [29] could be due to the chronic and aggressive effort in reducing the dietary GI to 39, which was the lowest value achievable among any published studies [8]. In addition, the calculated dietary GI at baseline was 53, indicating that the carbohydrate food choices in that study's subjects were already low in GI values due to their traditional diet, which consisted of beans, corn tortillas, pasta, pumpernickel bread, and legumes [28,29].

A significant association between dietary GI, GL, and changes in HbA_{1c} levels indicates that the larger the improvement in HbA_{1c}, the lower the intake of dietary GI and GL observed in the diet. This positive association was also supported by 2 different cross-sectional studies in patients with diabetes [30,31]. Interestingly, patients in the lowest quartile of dietary GI and GL exhibited the highest drop in HbA_{1c} level. However, no significant relationships between total carbohydrate intake and the clinical outcome or disease risk were observed in other observational studies [32,33].

There was a difference in the main carbohydrate food sources between the lowest and highest GI quartiles at week 12. Subjects in the lowest GI quartile consumed significantly less sources of white rice, wholemeal bread, condensed milk, starchy vegetables, and miscellaneous foods from the high GI varieties, but consumed more parboiled/basmati rice, pasta, milk/dairy products, fruits, and dough from the low GI varieties. Milk and dairy products are generally low in GI, regardless of their fat content [22], and this could explain the higher intake of calcium in subjects following low GI dietary advice. In a correlation analysis, dietary calcium was inversely related to dietary GI ($p < 0.001$; $r = -0.55$), which confirms this relationship between dietary calcium and GI intake. The food intake pattern in our subjects was similar to that observed in other low GI interventions. The dietary GI was reduced by using starchy foods such as whole-grain bread, legumes, pasta, oats, parboiled rice, bulgur, barley, and temperate fruit choices [28,29].

Low GI dietary advice has been perceived as complex and difficult to understand and place unnecessary burden on patients with diabetes [12]. It has been hypothesized that subjects given low GI dietary advice would not be able to adhere closely to the dietary regimen. Nevertheless, in our study, the proportion of subjects who adhered to the diet did not differ significantly between groups. This finding indicates that simple qualitative advice focusing on types of carbohydrate may be just as effective in managing diabetes as conventional measured carbohydrate exchange. Conflicting results have been observed in children with type 1 diabetes in which the use of measured carbohydrate diet resulted in relatively higher nonadherence to dietary instructions than in subjects in the low GI group [14]. However, we do admit that there are differences in standard dietary education, which may vary between countries and is affected by cultural environment.

Several limitations apply to our study. Adherence to dietary advice is a factor that influences all diet-related studies, including the current study. A high prevalence of underreporting of energy intake in this study would influence the accuracy of estimating the absolute nutrient intake and dietary GI and GL. The effect of underreporting on the calculated dietary GI has not been studied and therefore is unknown [6]. However, any error that may arise from underreporting would be expected to affect both groups to the same degree. In addition, the food diary, as with most others in intervention studies, was not developed with GI/GL estimation in mind; thus, no validation data for dietary GI estimation exist. Furthermore, the availability of low GI foods in this country is limited and they are expensive, which compromise diet variety, food choices, and palatability. Therefore, the results of our study need to be interpreted with caution in light of these limitations. However, despite these limitations, the practicality of a low GI dietary intake in Asian patients with T2DM is feasible, as illustrated by our study.

CONCLUSIONS

Low GI dietary advice does not result in a deterioration of dietary quality by increasing fat intake in the diet. Indeed, subjects in the GI group had greater consumption of crude fiber and calcium than did those in the conventional dietary advice group. The modest improvement in glycemic and metabolic parameters seen in our subjects on a low GI diet has provided another dietary management option for managing diabetes and its comorbidities among Asian patients. Further research is required to determine the reliability and validity of using food records for qualitative assessment of dietary carbohydrate intake. This would assist any research regarding long-term practicalities of maintaining low GI dietary intake in a traditional Asian diet.

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