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Original Communication
The glycaemic index values of Vietnamese foods

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Objective: To determine and compare the glycaemic index (GI) values of a range of Vietnamese foods in two racial groups.
Design and subjects: Twelve healthy subjects (six Asian and six Caucasian) consumed 50 g carbohydrate portions of a reference food (glucose sugar) and nine Vietnamese foods (three rices, three noodle products and three sweet foods) in random order after an overnight fast. The reference food was tested on two separate occasions, and the Vietnamese foods were each tested once. Capillary blood samples were taken at time 0 (fasting), 15, 30, 45, 60, 90 and 120 min from the start of each meal. Samples were analysed for plasma glucose and the incremental areas under the plasma glucose curves (AUC) were used to calculate the GI values of the test foods, using glucose as the reference food (ie GI value of glucose = 100). The mean GI value of each food was calculated for the entire group of subjects ($n = 12$) and for both racial groups ($n = 6$).
Results: The three rices had surprisingly high GI values (86 – 109), whereas the noodle products had relatively low GI values (39 – 61). The sugar-rich foods produced intermediate GI values (54 – 79). The GI values for the nine foods calculated separately for the two racial groups were not significantly different from each other ($P = 0.26$).
Conclusions: The GI values derived from Caucasian subjects are likely to be applicable to Asian populations. Varieties of imported rice from Thailand were found to have high GI values. Alternative low-GI staples, such as rice noodles, may be preferable for Asian/Vietnamese people with diabetes.
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Descriptors: glycaemic index; diabetes; rice; noodles; Vietnamese; ethnicity
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Introduction

The glycaemic index (GI) of foods has important implications for the prevention and treatment of the major causes of morbidity and mortality in Western countries, including non-insulin-dependent diabetes, coronary heart disease and obesity. The recent United Nations FAO/WHO Consultation on Carbohydrates (FAO/WHO, 1998) recommended that the GI of foods be used in conjunction with information about food composition to guide food choices. Specifically, it was recommended that at least 55% of energy be derived from carbohydrate and that the bulk of carbohydrate-rich foods should be those rich in dietary fibre and with a low GI ranking. While these recommendations are designed for the general population, there is persuasive evidence that they are especially important for people with diabetes. Medium-term crossover studies comparing the effects of diets with a similar macronutrient content but differing in their glycaemic impact have found that low GI diets are more beneficial for diabetes control (Brand *et al*, 1991; Jarvi *et al*, 1999). In addition, low-GI diets have the capacity to normalise levels of blood clotting factors, such as plasminogen activator inhibitor 1, whereas clotting factor levels remain elevated on a high-GI diet (Jarvi *et al*, 1999).

Results from recent large prospective studies have shown that the long-term consumption of a diet with a high ‘glycaemic load’ (GI×energy-adjusted amount of carbohydrate) is associated with an increased risk of developing type 2 diabetes (DM2) in men and women (Salmerón *et al*, 1997a,b). Results from animal and human studies have shown that chronic hyperglycaemia and hyperinsulinaemia are directly implicated in the progression of insulin resistance and reduced insulin secretion (Byrnes *et al*, 1995; Frost *et al*, 1996). Therefore, the chronic consumption of high-GI foods, which would

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Contributors: HMSC, JCB-M and SHAH devised and implemented the study and wrote the paper. DW and MR provided some of the foods and helped with the selection of foods for the study. PP carried out the statistical analyses.
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result in recurring, large postprandial fluctuations in blood glucose and insulin levels, could worsen insulin resistance in susceptible populations (Jenkins *et al*, 1987). The insulin resistance syndrome is already prevalent in young adults in diabetic-prone populations, including Chinese and other Asian populations (Lee *et al*, 1999). In Australia, Vietnamese women have one of the highest rates of gestational diabetes (Beischer *et al*, 1991; Shelly-Jones *et al*, 1993).

Asian migrants, particularly the Vietnamese, represent an increasing proportion of the Australian population (ABS, 1997–1998). Their high susceptibility to DM2 makes culturally appropriate dietary counselling essential, both for the treatment and prevention of DM2. Generally, they are advised to maintain their traditional low-fat dietary habits, rather than adopt Western eating habits. In the traditional Vietnamese diet, rice is eaten several times a day in large quantities, and is the major dietary source of carbohydrate. It has been widely assumed that traditional Vietnamese carbohydrate-rich foods have lower GI values than Western carbohydrate staples, such as bread, breakfast cereals and potatoes. However, the GI values of most Vietnamese staple foods have not been measured. Given that Asian immigrants in Western countries have a relatively high risk of developing DM2, it would be useful to measure the GI values of the carbohydrate-rich staple foods used by these ethnic groups, before and after migration. This would assist the development of more culturally appropriate dietary advice for the treatment and prevention of diabetes in these populations.

One of the questions frequently raised in relation to the GI is whether results obtained using Caucasian subjects can be applied to other ethnic groups. Previous research has shown that GI values determined in different groups of subjects with varying degrees of glucose tolerance are directly comparable (Wolever *et al*, 1987). This is because the use of a standard reference food controls for inter-individual differences in glycaemic responses to food (Jenkins *et al*, 1984). Therefore, in theory, racial differences in glucose tolerance should not affect GI values. Very little research, however, has addressed this question. Walker and Walker (1984) found that rural African subjects and Caucasian subjects had similar GI values for the same foods. However, the prevalence of diabetes in these two groups is low (Jackson, 1978). It remains to be examined whether larger inter-racial differences in GI values for the same foods exist between populations with a low *vs* a relatively high prevalence of diabetes, such as Caucasians *vs* Asian immigrants living in Western countries.

Methods and materials

Subjects

Twelve healthy volunteers (six Asian, six Caucasian) were recruited from the student population of the University of Sydney. Of the Asian subjects, three had migrated from China, two from Indonesia and one from Vietnam. Four of these subjects were foreign students temporarily living in Australia (time in Australia 1–2 y), and two were permanent residents (time in Australia 8–12 y). All of the Asian subjects regularly consumed Asian foods at main meals, but often consumed Western-type foods as snacks. Rice was the main source of dietary carbohydrate for all of the Asian subjects. The mean age ± s.d. of the Asian and Caucasian subjects was 23 ± 6 and 21 ± 1 y, respectively. The mean body mass index (BMI) ± s.d. was $20.6 \pm 1.2\,kg/m^2$ for the Asian subjects and $22.1 \pm 1.8\,kg/m^2$ for the Caucasian subjects. The study was approved by the Medical Ethics Committee of the University of Sydney and all volunteers gave informed written consent before participating.

Test foods

Each of the 12 subjects consumed portions of the nine test foods and the reference food (Glucodin® glucose powder, Boots Healthcare, Australia) containing 50 g of available carbohydrate on separate mornings over a 6 week period. The reference food was consumed on two separate occasions, on the first and last test sessions of the study, and the nine test foods were consumed once only in random order between the two reference food tests. The relevant details

Table 1 The available carbohydrate contents of the test foods based on the raw products, the weights of the test portions of the foods containing 50 g of available carbohydrate, and the amount of additional water required to bring the meal volumes to 750 ml

Test food	*Country of origin*	*Available carbohydrate (g/100 g)*	*Portion weight (g)*	*Additional water (ml)*
1. Rice noodles, dried[a]	Thailand	81.5[c]	61.3	600
2. Rice noodles, fresh	Australia	45.5[c]	110	622
3. Mung bean noodles[b]	China	82.8[c]	60.4	494
4. Glutinous rice	Thailand	76.3[c]	65.5	612
5. Jasmine rice, long grain	Thailand	79.1[d]	63.2	612
6. Broken rice	Thailand	79.1[d]	63.2	616
7. Lychee, canned and drained	China	17.1[d]	292.4	466
8. Custard apple	Australia	15.8[d]	316.5	439
9. Milk, condensed sweetened	Australia	55.4[d]	90.2	683

[a]Alternative name is rice vermicelli.
[b]Alternative names are lungkow bean thread or vermicelli.
[c]Food composition tables for use in East Asia. FAO and US Department of Health, Education and Welfare, 1972. CHO values are total carbohydrate content minus fibre.
[d]Nutritional Values of Australian Foods. National Food Authority, Canberra 1992.

of the test foods are listed in Table 1. The nine test foods were grouped into three food categories: noodles ($n=3$); rices ($n=3$); and sweet foods ($n=3$).

The reference food was prepared the day before required by dissolving 50 g of pure glucose powder in a glass of 250 ml of warm water, which was then covered and stored overnight in a fridge. The next morning, the glucose solution was brought to room temperature 30 min before serving. The required portions of test foods were prepared fresh, shortly before required for testing. The two types of rice noodles were both soaked in excess hot water for 5 min and mung bean noodles were soaked in hot water for 8 min, and then drained. The three types of rice (glutinous, jasmine and broken) were all cooked in an electric rice cooker (420 W) using two volumes of water for each weight of rice. The rices were cooked fresh each morning to avoid starch retrogradation. Canned lychees were drained and consumed without the sugar syrup in the can. Custard apples were tested ripe when they were soft to touch, and the peeled, seedless flesh was served to the subjects. The subjects were asked to drink any juice left in the serving dish. For each test food and reference food, additional water was served to bring the total meal volume to 750 ml.

Experimental protocol
The night before a test session, the subjects ate a regular evening meal and then fasted for 10–12 h overnight before the start of their test session the next morning. The subjects were required to consume a similar evening meal the night before each test session, and refrain from consuming legumes, in order to avoid the 'second meal effect' (Wolever *et al*, 1988). Subjects were required to avoid alcohol and unusual amounts of exercise and eating for the entire day before each test session. Subjects were allowed to drink only water during the fasting period. The next morning, the subjects reported to the research centre in a fasting condition. After 10–15 min, baseline blood glucose levels were obtained by collecting two finger-prick capillary blood samples (0.5 ml), taken 5 min apart (−5 min, 0 min). After the fasting blood samples were obtained, subjects were given a fixed portion of a test food or reference food, which they consumed with additional plain water at a comfortable pace within 10 min. The subjects were then required to remain seated at the research centre and refrain from additional eating and drinking during the next 2 h. Additional finger-prick blood samples were taken 15, 30, 45, 60, 90 and 120 min after eating had commenced. To improve peripheral blood circulation to fingers, subjects warmed their hands with hot water bottles for 5 min before each blood sampling. Blood samples were obtained using an automatic lancet device (Autoclix®, Boehringer Mannheim, Australia), and the blood was collected into 1.5 ml microcentrifuge tubes coated with heparin (8 IU heparin sodium salt, Sigma Chemical Co., St Louis, USA). Blood samples were immediately centrifuged after collection at 12 000 *g* for 1 min. The plasma component was collected into an uncoated plastic tube and then immediately stored at −20°C for later analysis (< 1 month).

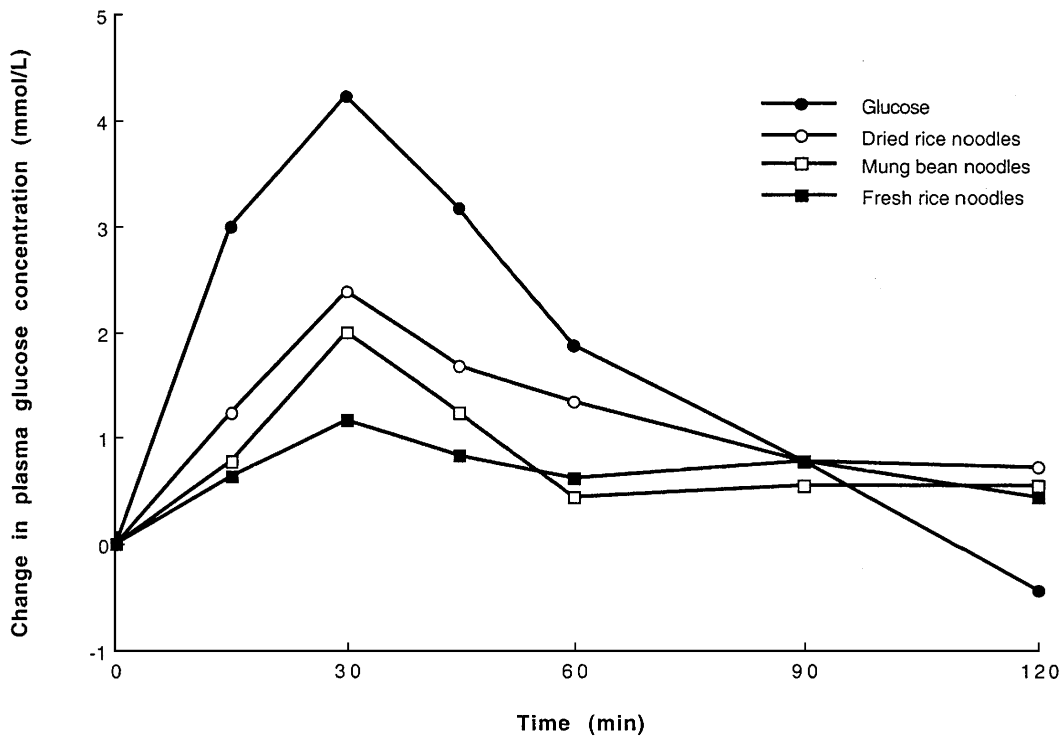
Measurement of blood glucose concentrations and GI values
Plasma samples were thawed at room temperature, vortexed and centrifuged before analysis. Photometric analyses were performed in duplicate on a Cobas-Fara centrifugal analyser (Roche Diagnostica, Basle, Switzerland), using the hexokinase/glucose-6-phosphate dehydrogenase enzymatic method (Roche Diagnostic Systems, Frenchs Forest, Australia). Inter- and intra-assay coefficients of variation were 1.2 and 0.8%, respectively. The incremental area under the plasma glucose curve (AUC) was calculated according to the trapezoidal (Simpson's) rule using the area above baseline (fasting glucose) only (Wolever *et al*, 1991). The average AUC of the two reference food tests was used as the reference value for calculating the GI values for the test foods. For each subject, a GI value for each test food was calculated by dividing the 120 min blood glucose AUC value for this test food by the subject's average 120 min blood glucose AUC value for the reference food and multiplying by 100 to obtain a percentage score.

$$\text{GI score for test food \%} = \frac{\text{120 min glucose AUC value for the test food}}{\text{Mean AUC value for the same carbohydrate portion of the reference food}} \times 100$$

Due to differences in body weight and metabolism, blood glucose responses to the same food can vary between different people. The use of the reference food to calculate GI scores reduces the variation between the subjects' blood glucose results to the same food arising from these natural differences. Therefore, the GI score for the same food varies less between the subjects than their glucose AUC values for this food. Mean ± s.e.m. GI values were calculated for each food for the combined group of subjects ($n=12$) and for each racial group ($n=6$). Individual GI values for any subjects that were greater than two standard deviations from the mean of the group were considered to be outliers and were excluded from the data set.

Power of study and statistical analyses
With six subjects in each group and a significance level of 5%, we had a power of 88% to detect a 50% difference between the means of the two ethnic groups (corresponding to two standard deviations). Analysis of variance (ANOVA) (general linear model) was used to determine whether significant differences existed between: the GI values for the three food groups; GI and AUC values of test foods for each racial group; and fasting and 120 min blood glucose AUC values between the two racial groups. ANOVA was performed using ethnic group as a fixed factor and subjects within each racial group as random factors, allowing for individual variations. The rank order of GI values for each racial group was compared using the Spearman rank correlation (r_s) test. Pearson's correlation was used to determine whether there were any significant

a. Noodles



b. Rice

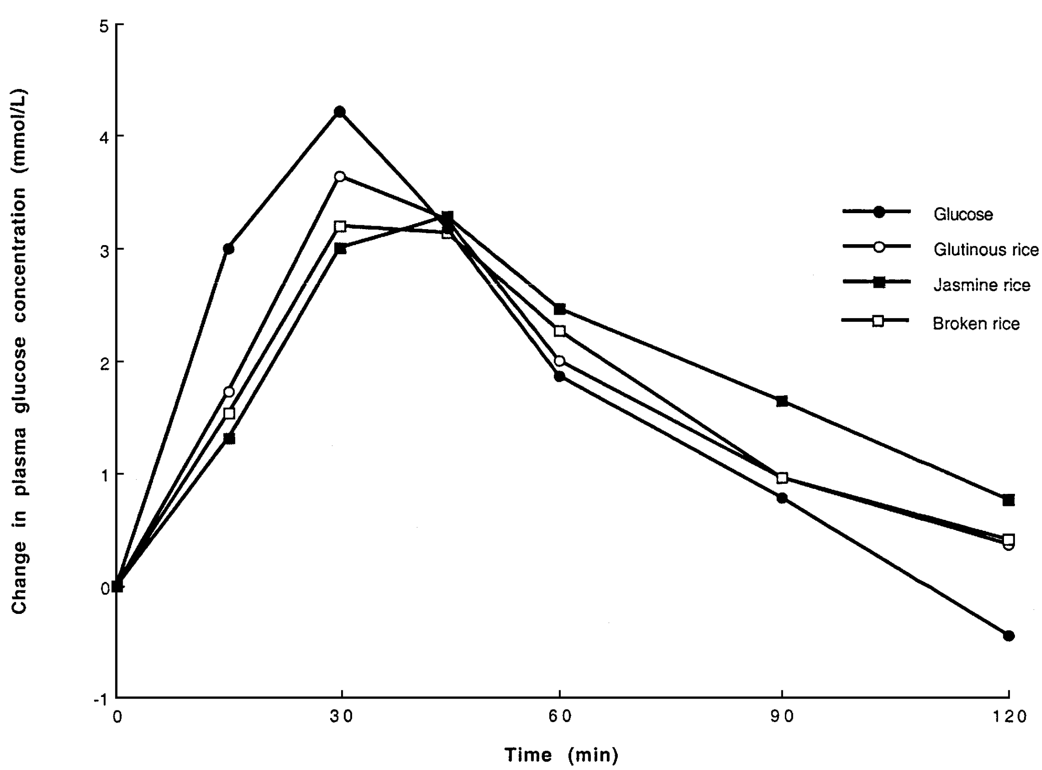


Figure 1 (*continued*)

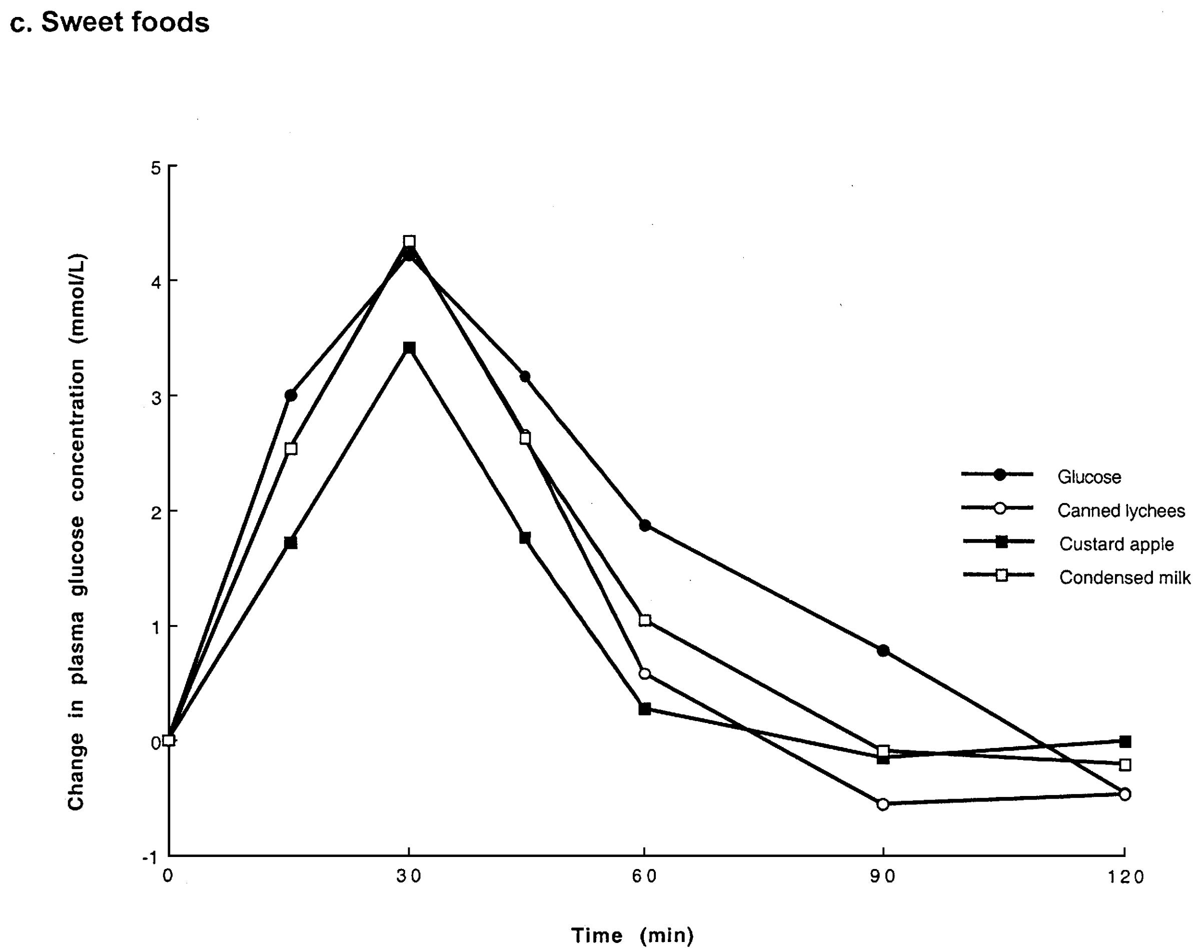


Figure 1 The mean incremental changes in plasma glucose concentrations following the consumption of the nine test foods: noodle products (a), rices (b) and sweet foods (c) ($n = 12$).

differences in GI values for the test foods between the two racial groups. Significance was assumed at $P < 0.05$.

Results

As shown in Figure 1, there was an almost 3-fold range in blood glucose responses among the traditional Vietnamese foods. Consequently, there were marked differences in the GI values among the test foods and between the food categories (Table 2). The noodle products had lower mean GI values (39–61) than the rices (86–109), and the sugar-rich foods produced intermediate GI values (54–79). Using the combined GI values for both racial groups ($n = 12$), the mean GI value for the glutinous rice was significantly greater than the mean GI values for the fresh rice noodles ($P < 0.001$), dried rice noodles, custard apple ($P < 0.01$), mung bean noodles and condensed milk ($P < 0.05$). The mean GI value for the jasmine rice was significantly greater than the mean GI values for the three types of noodles, custard apple ($P < 0.001$), condensed milk ($P < 0.01$), and lychees ($P < 0.05$). The mean GI value for the broken rice was significantly greater than the mean GI values for the fresh rice noodles ($P < 0.001$), custard apple ($P < 0.01$), condensed milk, dried rice noodles and mung bean noodles ($P < 0.05$). The mean GI value for the lychees was significantly greater than the mean GI value for the fresh rice noodles ($P < 0.01$).

No statistical differences were found among the AUC or GI values between the two racial groups ($P = 0.40$ for AUC, and $P = 0.26$ for GI). For most of the foods, the average GI value for the Caucasian group was slightly higher than the average value for the Asian group (Table 2), but this was largely due to higher results produced by only one or two subjects in this group. The mean GI values of the nine test foods for the two racial groups were significantly associated ($r = 0.88$, $P = 0.002$, Figure 2). In addition, the rank order of the GI values for the nine test foods was similar for both ethnic groups ($r_s = 0.82$, $P < 0.01$). Fasting and 120 min blood glucose AUC values were slightly higher in the Asian subjects, but the differences were not significant ($P = 0.40$ and $P = 0.79$).

Table 2 The mean ± s.e.m. glycaemic index (GI) values of the test foods (glucose = 100) for the combined groups of subjects ($n = 12$, unless outliers excluded), and the two separate racial groups ($n = 6$, unless outliers excluded)

Test foods		*All subjects*	*Caucasian*	*Asian*
Noodles	Mung bean noodles	39 ± 9 ($n = 11$)	51 ± 16 ($n = 5$)	28 ± 9
	Rice noodles, dried	61 ± 6	65 ± 8	57 ± 9
	Rice noodles fresh	40 ± 5	47 ± 8	34 ± 4
Rices	Broken rice[a]	86 ± 8 ($n = 11$)	107 ± 17	79 ± 10
	Glutinous rice[b]	94 ± 6 ($n = 11$)	101 ± 11	95 ± 9
	Jasmine rice, long grain[c]	109 ± 10	123 ± 17	94 ± 8
Sweet foods	Custard apple, fresh	58 ± 5	51 ± 7	65 ± 8
	Lychees, canned, drained[d]	79 ± 8	81 ± 13	76 ± 10
	Milk, full-cream condensed, sweetened	61 ± 6 ($n = 11$)	71 ± 14	62 ± 8

Significant differences among the foods' mean GI values using the entire group of subjects ($n = 12$):
[a]Broken rice > fresh rice noodles ($P < 0.001$), custard apple ($P < 0.01$), condensed milk, dried rice and mung bean noodles ($P < 0.05$);
[b]Glutinous rice > fresh rice noodles ($P < 0.001$), dried rice noodles, custard apple ($P < 0.01$), condensed milk and mung bean noodles ($P < 0.05$);
[c]Jasmine rice > all three noodles, custard apple ($P < 0.001$), condensed milk ($P < 0.01$) and lychees ($P < 0.05$);
[d]Lychees > fresh rice noodles ($P < 0.01$).

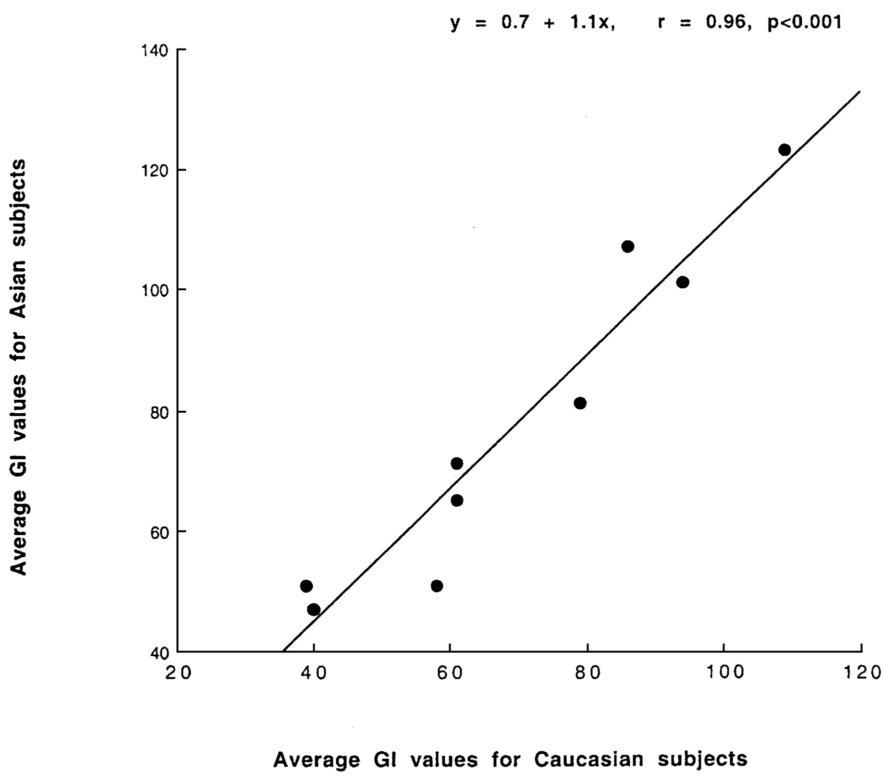


Figure 2 The relationship between the GI values for the nine test foods between the Asian and Caucasian subjects.

Discussion

In addition to the generation of new GI data, the novel finding in this study is that the GI values determined in two racial groups were not significantly different, in either a statistical or biological sense. The largest difference in GI values between the two groups occurred for 'broken rice', for which the Caucasian subjects had a mean GI value that was 26% higher than the Asian subjects' (107 *vs* 79). However, both of these GI values are considered to be high (Brand-Miller *et al*, 1999). Of greater relevance than the absolute value, however, is the rank order of test foods, which was highly correlated in the Caucasian and Asian groups ($r = 0.82$, $P < 0.01$). Although the number of subjects used in this study was small, the study provides reassuring evidence that the GI concept is applicable to different types of subjects and different populations. To fully address the question of inter-racial differences, further research in other ethnic groups and in older, obese and diabetic individuals should be conducted.

Another novel finding in this study was that the Vietnamese rices had surprisingly high GI values (86–109), similar to many varieties of Australian rice (Foster-Powell & Brand-Miller, 1995). Therefore, advising Vietnamese people to consume Asian varieties of rice rather than Australian varieties would appear to offer no advantage in terms of reducing the glycaemic impact of their diet. However, new high-yielding varieties of rice that contain relatively low amounts of amylose have been introduced in Asian countries in recent years and subsequently imported into Australia. Therefore, it is likely that the types of rice tested in this study represent these new varieties rather than older traditional types containing more amylose. Previous studies have shown that high-amylose varieties of rice have lower GI values than low-amylose types (Brand-Miller *et al*, 1995; Holt & Brand-Miller, 1995). In addition, faster industrial methods of rice milling have progressively replaced traditional methods in Asian countries, which may increase the amount of cracking within the grain and result in increased starch gelatinisation and digestibility and higher postprandial glycaemia. Clearly, because the GI values of different varieties of rice vary so markedly, there is a need for a large-scale study of new and old varieties of rice from around the world.

Mung bean noodles and rice noodles have been previously tested in Canadian studies (Foster-Powell & Brand-Miller, 1995). The GI value for the mung bean noodles tested in this study was higher than previously recorded (39 *vs* 26), but nonetheless still low. The GI value for dried rice noodles (also known as vermicelli) tested in this study was similar to the previously recorded value (61 *vs* 58). The relatively low GI values of these noodle products might be due to their amylose content (Wolever, 1990). In a previous study, mung bean noodle starch was found to contain 47% amylose while *indica* rice vermicelli contained 28% amylose (Juliano *et al*, 1989).

The three sweet foods tested in this study (one fresh fruit, one canned fruit and condensed milk) had a wide range of GI values (38–79), although these were all lower than GI values for the rice products. It challenges conventional wisdom that these sugary foods, especially condensed milk, produced less glycaemia than the starchy foods. Fruits, such as peaches canned in light or heavy sugar syrup have been found to have higher GI values than fresh peaches or fruit canned in juice (Brand-Miller *et al*, 1995). Differences in acidity or osmolality have been shown to influence the GI of fresh fruit and vegetables (Wills *et al*, 1998) and might also explain the high GI value of the canned lychees tested in this study.

The high GI values of the Asian rices tested in this study raises doubts about the desirability of recommending them to patients with diabetes, particularly gestational diabetes. Due to their high carbohydrate contents (75–80% dry weight), these foods are capable of inducing significant glycaemia in normal serving sizes. Culturally sensitive dietary advice might therefore emphasise noodle products in place of rice. Other rices such as the high—amylose Doongara, Basmati or short grain Japonica (Matsuo *et al*, 1999) with lower GI values could also be substituted for high GI rices.

In conclusion, our findings indicate, firstly, that many 'traditional' starchy foods may have higher GI values than might be expected and, secondly, that the ranking of foods according to their GI values is likely to be similar for both Caucasian and Asian subjects. Further studies of inter-racial differences in a wider range of subjects are warranted. Knowledge of the GI values of Vietnamese foods may assist in the development of better dietary advice for Asian people with diabetes.

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