Effect of Long-term Intake of Asian Food with Different Glycemic Indices on Diabetic Control and Protein Conservation in Type 2 Diabetic Patients

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Abstract

The study was carried out in 10 females with type 2 diabetes aged 32-60 yrs. All of them were receiving weight-maintaining diets composed of 12 per cent protein, 30 per cent fat and 58 per cent carbohydrate. The only difference among all study-diets was the types of complex carbohydrate used. High-glycemic diet (HG) or low glycemic diet (LG) consisted mainly of glutinous rice or mungbean noodles and the intermediate-glycemic diet (DM) was solely white rice. After the metabolic evaluation of the baseline diet (BL), each subject was placed on DM and followed randomly by HG and LG or vice versa for 4 weeks each. The diurnal plasma glucose levels tended to be lowest after LG. The integrated plasma glucose levels among all diets were not different. The integrated insulin levels after DM and LG did not differ but they were lower than HG and BL. Long-term ingestion of all test-diets spilt less urinary glucose than BL, the lowest was LG. HbA_1 levels and nitrogen balance after all diets were better than BL, the best was LG. It was concluded that in addition to strict dietary control, ingestion of mungbean noodles (a low glycemic diet) without increasing fiber intake, can improve diabetic control and protein conservation in type 2 diabetes.

Key word : Diabetic Diet, Mungbean Noodles, Glycemic Index, Glycemic Indices, Glutinous Rice, Sticky Rice, Asian Food, Rice

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Diabetes usually results from an absolute or relative deficiency of insulin. In the course of low serum insulin, glucose, fatty acids and amino acids are not transported into cells, protein synthesis stops and protein catabolism is activated. In addition, protein metabolism is more sensitive

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to insulinization than was thought previously(1). Hence, uncontrolled diabetes not only brings about hyperglycemia and abnormal lipid metabolism but also alteration of protein metabolism (negative nitrogen balance) which could be improved with restoration of normoglycemia(2). The primary goal of nutritional therapy is to achieve normal or physiologic blood glucose levels by optimizing glucose use, normalizing glucose production, and enhancing insulin sensitivity(3). High-carbohydrate in the presence of a high-fiber diet has been recommended for the nutritional management of patients with diabetes mellitus(4). However, increased fiber intake especially beans and legumes may cause gastrointestinal discomfort and possible mineral depletion (5). Therefore, it is essential to search for diets which can produce good glycemic control without having to consume a large amount of fibers. Komindr et al(6) showed that acute plasma glucose response after the ingestion of a meal containing mungbean-noodles as the main carbohydrate source was lower than that after rice and glutinous rice (sticky rice). The study also showed a series of glycemic indices for carbohydrates in the Thai diet. Since these carbohydrates are normally consumed by healthy people in Asia and by diabetics as well, it was our intention to see whether long-term consumption of these carbohydrates without an increase of dietary fiber can improve the glucose control, insulin sensitivity and the protein sparing in NIDDM patients.

MATERIAL AND METHOD

Patient selection

The study was conducted in 10 female non-insulin-dependent diabetics, aged 32-60 years who had been treated with diet alone or diet and oral hypoglycemic agents for 2 to 7 yrs and had fasting plasma glucose levels between 140 to 280 mg/dL. Inclusion criteria for the study were absence of diabetic complications, co-operative, ability to consume the different test-diets, ability to keep detailed food records and be followed-up for at least 4 months. The objectives and details of the study were explained to all subjects. After obtaining written consent, the subjects were randomly divided into 2 groups, A and B. Dietary habit interviews and daily dietary records were collected for 6 weeks prior to the study (while their weights were stable within a range of 2 kg) and during the first 3 days of the baseline period for creation of the individualized weight-maintaining diabetic diets (study-diets).

Study design

Group	Baseline study	Diabetic-diet period		
A	*BL*	*DM*	*HG*	*LG*
B	*BL*	*DM*	*LG*	*HG*
Duration	*usual diet*	*4 wks*	*4 wks*	*4 wks*

The subjects were admitted into the clinical research center consuming their own usual diet as the baseline diet (BL) for 3 days. This was followed by consumption of one of the DM study-diets according to the randomization (A or B) during the remaining 2 days of admission. The subjects were then discharged and the study-diet was continued at home (while the preweighed test-carbohydrates were obtained from the metabolic kitchen) for a total duration of 4 wks. At the end of wk 4, the subject was readmitted to the center for evaluation of the effects of the present diet and initiation of a new study-diet. Each diet lasted 4 wks, together with the preadmission period making a total study time of 129 days for each patient. There was no adjustment of the medicine used in the treatment of diabetes during the study. During days 1 and 2 of each admission, the long-term effect of the present diet was evaluated.

Dietary detail

Baseline diet (BL) was the usual self-selected diet consumed by the subjects during the first 3 days of the first admission. BL diet in conjunction with the habitual dietary detail were used as a guide for creating the individualized weight-maintaining diabetic diet (DM), high glycemic diabetic diet (HG) and low glycemic diabetic diet (LG) according to the ADA dietary guide lines, consisting of 12 per cent protein, 30 per cent fat and 58 per cent carbohydrate (40% of total calories as complex carbohydrates, 5% as sucrose and the remaining 13% of calories as combination of vegetables and fruits). DM consisted solely of white rice (40% of daily calories), HG consisted mainly of glutinous rice and partly of rice-in-soup (35% of daily calories) and 5 per cent as white rice. LG consisted mainly of mungbean noodles and partly of rice noodles (35% of daily calories) and 5 per cent cooked rice. The subjects started a new test-diet on day

3 of each admission and continued until discharge on day 5. During each admission the subjects were taught in our metabolic kitchen to prepare their own test-diet, practiced and mastered the cooking procedure according to the pre-set 4-day rotating menu. Protein, fat, type and amount of vegetables were controlled, the only difference among the study-diets being the different complex carbohydrates used in the study (Table 1). Except for BL the whole period for a test diet was 28 days. During out-patient visits every 2 wks, the subjects obtained a 2-wk supply of pre-weighted carbohydrates and recipes from the metabolic kitchen.

Anthropometric measurements

Body weight, height, triceps, biceps, subscapular, and suprailiac skinfold thickness, waist and hip circumferences in each subject were measured by using the standard techniques (7) on the first day of each admission. The percentage of body fat was calculated according to the formula developed by Durnin and Wormesley (Br J Nutr 1974).

Biochemical evaluation

Fasting, post-prandial and diurnal blood samples from 8 am to 9 pm on days 1 and 4 were collected through a heparin well placed in one of the forearm veins for measurements of glucose, insulin, urea nitrogen, creatinine and albumin. On day 2 and day 5, plasma glucose response to an insulin tolerance test (0.08 unit of regular insulin per kg body weight) was carried out. Daily 24-h urine was collected for urinary urea nitrogen, glucose and creatinine during every admission. Glucose was determined by enzymatic method[8], glycosylated hemoglobin (HbA1) by the affinity chromatography technique[9], insulin by radioimmunoassay procedure (coat-A-count; diagnostic products corporation, U.S.A.). Urinary creatinine was determined by the colorimetric method[10], nitrogen by the Kjeldahl method (Kjeltec system; Tecater, Sweden).

Statistical analysis

The data from both groups were pooled, the results were reported as mean ± SEM values. Comparisons were made within each diet for short-term and long-term effects and between different diets using two-way analysis of variance and Wilcoxon matched-pair, signed-rank test[11].

RESULTS

The pre-admission daily energy consumption (mean ± SEM) of the subjects was 1474.18 ± 106.46 kcal (Table 2). The calorie distribution of protein, carbohydrate and fat was 13, 55 and 32 per cent of total calories, respectively with animal and vegetable fat covering approximately 14 and 18 per cent of total calories. The composition of carbohydrates consisted of 43.4 per cent of total calories as complex carbohydrate, 7.4 per cent as table sugar and 4.2 per cent as fruits. There were no significant changes in body weight, BMI, waist to hip ratio and the percentage of total body fat during different diets of the study (Fig. 1). However, the percentage of the total body fat was significantly lower during LG than the BL period. There were no significant decreases in the levels of serum albumin and hematocrit during all test diets (Table 3). The serum creatinine levels during LG were significantly higher than during HG, whereas, serum urea nitrogen levelsdid not change during the study.

Diurnal plasma glucose level during DM was statistically lower than during BL at 8.30 am which became significantly higher at 10.00 am and 8.00 pm (Fig. 2A) but there was no difference in the integrated plasma glucose levels between DM and BL (Fig. 3A). On the contrary, decreases in the serum insulin levels especially in the morning hours at 9.00 am, 11.00 am and 8.00 pm (Fig. 2B) as well as in the integrated serum insulin levels were evident during DM compared to BL (Fig. 3B). The diurnal plasma glucose levels during HG were higher than during BL at 10.00 am and 8.00 pm. There were no significant differences in diurnal PG, the integrated PG levels and their corresponding insulin levels between HG and BL during the rest of the day (Fig. 2-3). Although the diurnal plasma glucose levels during HG were higher than during DM at 9.00 am and 10.00 am, the integrated plasma glucose levels were not different. However, most of the serum insulin levels and the integrated serum insulin levels during HG were higher than DM

Table 1. Test-diet menus+.

Breakfast	Lunch	Dinner
A. Regular diabetic diet (DM)		
I. Cooked-rice, fried cabbage, fruit*	Fried rice with chicken, fruit	Cooked-rice, chicken fried with ginger, soup with Chinese cabbage, fruit
II. Cooked-rice, fried mixed vegetables, fruit* sweet sauce, cabbage soup, fruit	Cooked-rice, chicken fried with mixed vegetables in sour and	Chicken fried with Krapaw basil, chili and rice, fruit
III. Cooked-rice, fried cabbage, fruit	Fried rice with chicken, fruit	Cooked-rice, chicken fried with ginger, soup with cabbage, fruit
IV. Cooked-rice, fried mixed vegetables, fruit* sauce, cabbage soup, fruit	White-rice, chicken with mixed vegetables in sure and sweet	Chicken fried with Krapaw basil, chili and rice, fruit
B. High-glycemic diabetic diet (HG)		
I. Rice in soup with chicken, fruit*	Cooked-rice, fried chicken, cabbage soup, fruit	Sticky rice (Glutinous rice), boiled chicken mixed with chili, lemon, onion and tomato (Larb Kai), fruit
II. Rice in soup with chicken, fruit*	Cooked-rice, chicken fried with ginger, fruit	Sticky rice, chicken fried with basil and chili, fruit
III. Rice in soup, fried chicken with Peppers, fruit*	Cooked-rice, chicken and long beans fried in chili paste, mushroom in sour and hot soup (Tom-yum), fruit	Sticky rice, boiled chicken with chili, lemon, onion and tomato (Larb Kai), fruit
IV. Rice in soup with chicken, fruit* mixed vegetables in sauce, fruit	Cooked-rice, curry with mixed vegetables, chicken fried with	Sticky rice, grilled chicken in hot sauce(Kai Yang),fruit
C. Low-glycemic diabetic diet (LG)		
I. Chicken in rice-noodle with soup, fruit* (yum), fruit	Cooked-rice, mungbean noodle fried with chicken, cabbage soup,	Chicken in sour and hot mungbean noodle salad fruit
II. Rice noodle fried with chicken and Regetable, fruit*	Cooked-rice, chicken fried with mungbean noodle in chili paste,mixed vegetables in sour and hot soup(Tom Yum), fruit	Chicken with Krapaw basil,chili and mungbean noodle, fruit
III. Chicken fried with mungbean-noodle, fruit* fruit	Cooked-rice, chicken and long-beans fried with mungbean noodle in chili paste,mushroom in sour and hot soup (Tom Yum),	Chicken fried with rice-noodle, fruit
IV. Chicken in mungbean noodle with soup, fruit*	Cooked-rice, chicken fried with mixed vegetables in sour and sweet sauce, chicken curry with mungbean noodle, fruit	Chicken fried with rice-noodle, fruit

+ Each diet consisted of 4 rotating menus: I, II, III, IV

* Either guava, tamarine, papaya, or pine-apple; fruit selection was fixed according to the test procedure.

Table 2. Pre-admission dietary intake of 10 NIDDM subjects.

No.	CHO (%) Complex	CHO (%) sugar	CHO (%) fruit	Total CHo (%)	Protein (%) A	Protein (%) V	Total protein (%)	Fat (%) A	Fat (%) V	Total fat (%)	Total intake (kcal)
1	32.50	9.50	5.80	47.80	9.50	5.80	15.30	20.00	16.80	36.80	2008
2	48.30	5.80	3.00	57.10	7.20	6.70	13.90	13.70	15.30	29.00	1710
3	46.60	5.70	4.10	56.40	9.40	4.20	13.60	16.70	13.30	30.00	1504
4	49.00	6.10	6.30	61.40	7.20	5.40	12.60	11.20	14.60	25.80	1368
5	53.40	2.60	5.00	61.00	4.10	7.20	11.30	2.80	24.80	27.60	1225
6	48.30	1.89	4.97	55.16	14.89	4.74	19.63	10.50	14.60	25.10	1058
7	34.00	19.50	2.10	55.60	7.70	4.50	12.20	19.60	12.40	32.00	1162
8	37.50	8.20	4.80	50.50	6.50	7.00	13.50	8.90	27.10	36.00	2018
9	42.00	10.30	4.60	56.90	5.50	3.80	9.30	12.70	21.00	33.70	1380
10	42.40	4.00	1.40	47.80	7.00	6.40	13.40	19.00	19.80	38.80	1305
Mean	43.40	7.35	4.20	54.97	7.89	5.57	13.47	13.51	17.97	31.48	1474
SEM	2.19	1.61	0.49	1.53	0.93	0.38	0.85	1.73	1.58	1.50	106

A and V represent percentage of protein and fat derived from animal and vegetable sources, respectively.

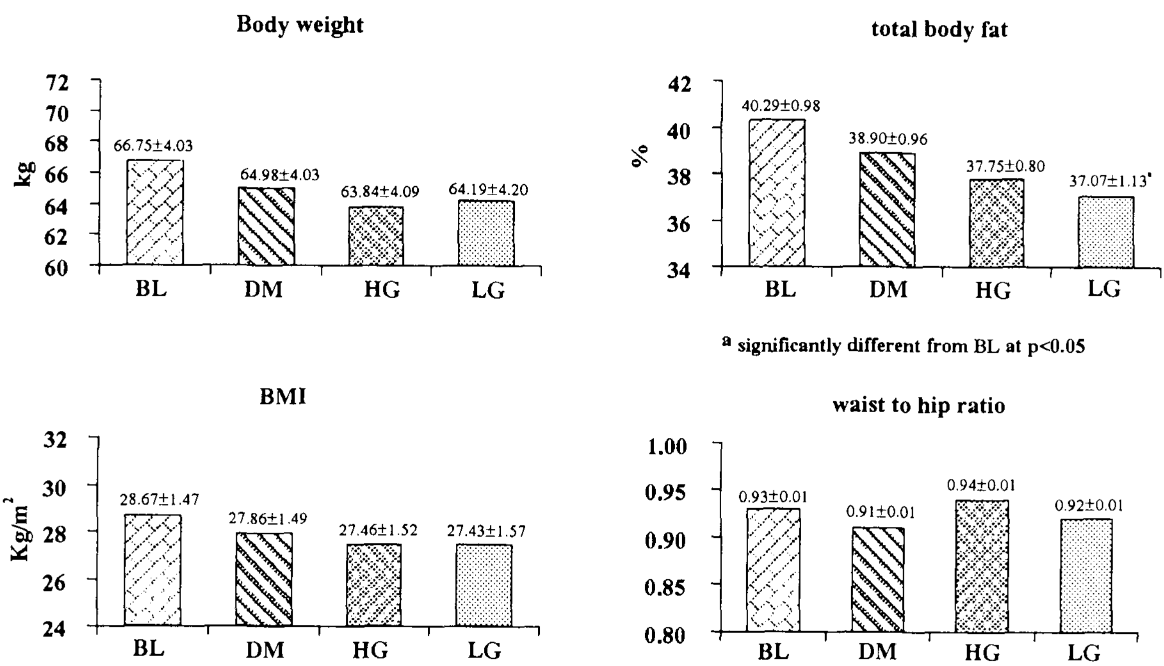

Fig. 1. Comparison of body weight, BMI, body fat (%) and waist to hip ratio in 10 patients after long-term intake of diets with various glycemic indices.

(Fig. 2-3). Most of the diurnal plasma glucose levels during the LG diet were lower than all diets but showed significant differences from BL at 12.00 am, from DM at 12.00 am and 8.00 pm and from HG at 9.00 am (Fig. 2). The LG diet also produced the lowest integrated plasma

Table 3. **Comparison of biochemical assessments (mean ± SEM) of patients 4 wk after diets with various glycemic indices.**

Parameter	BL	DM	HG	LG
Hct, %	38.82 ± 1.24	38.65 ± 1.39	37.50 ± 1.07	37.70 ± 1.38
RBC, x 10^6 /L	5.02 ± 0.31	4.22 ± 0.18	4.67 ± 0.20	4.47 ± 0.14
White cell count, x 10^3 /L	8.56 ± 1.25	6.29 ± 0.64	6.77 ± 0.72	5.98 ± 0.71
S. albumin, mg/dL	4.28 ± 0.12	4.21 ± 0.09	4.20 ± 0.12	4.02 ± 0.13
S. urea nitrogen (SUN), mg/dL	11.87 ± 1.14	11.37 ± 1.14	11.68 ± 0.20	10.28 ± 1.06
S. creatinine, mg/dL	0.85 ± 0.05	0.87 ± 0.02	0.80 ± 0.02	0.97 ± 0.05*
S. Alanine-aminotransferase	27.30 ± 4.33	20.10 ± 2.82	20.20 ± 3.06	17.60 ± 1.89
S. Alkaline phosphatase, u/L	74.50 ± 7.08	71.20 ± 4.59	78.00 ± 7.41	63.80 ± 4.92
Sodium, mEq/L	141.10 ± 1.35	140.20 ± 0.64	139.50 ± 0.68	139.60 ± 0.54
Potassium, mEq/L	3.99 ± 0.07	4.06 ± 0.06	3.93 ± 0.07	4.11 ± 0.07

* Significantly different from HG at p< 0.05

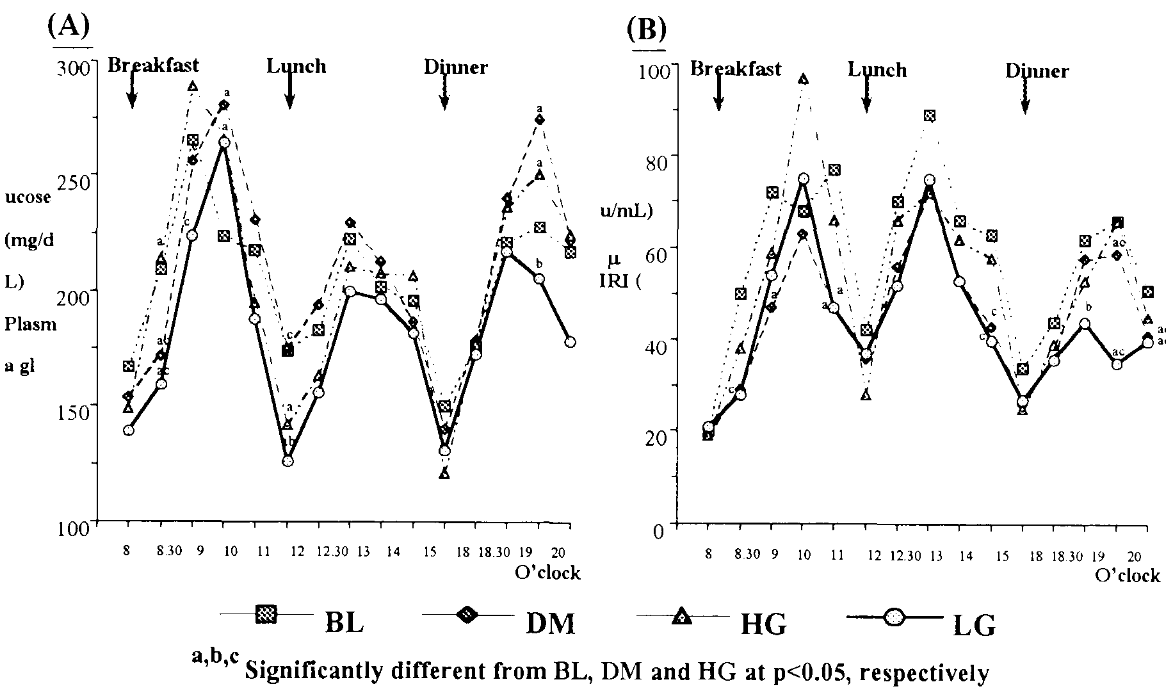

Fig. 2. **Diurnal variation of plasma glucose (A) and insulin levels (B) during long-term intake of diets with various glycemic indices.**

glucose among all diets. The diurnal serum insulin levels during LG were significantly lower than at 11.00 am and 9.00 pm, and HG at 3.00 pm and 8.00 pm. However, LG produced a significantly lower integrated serum insulin level than BL and HG.

The maximum reduction in plasma glucose after insulin injection was greatest with LG (-81 ± 6 mg/dL) compared to BL, DM and HG (-65 ± 9, -70 ± 7, and -71 ± 7 mg/dL, respectively) (Fig. 4A). The nadir of plasma glucose during DM,

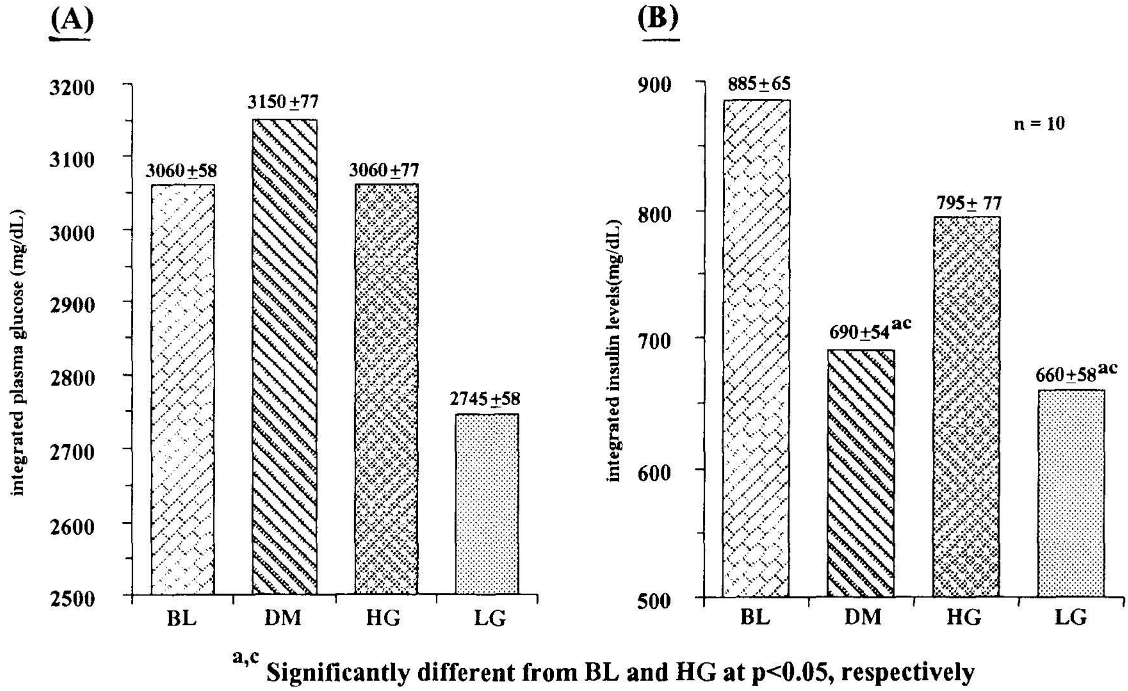

Fig. 3. Comparison of integrated of plasma glucose (A) and insulin levels (B) during long-term intake of diets with various glycemic indices.

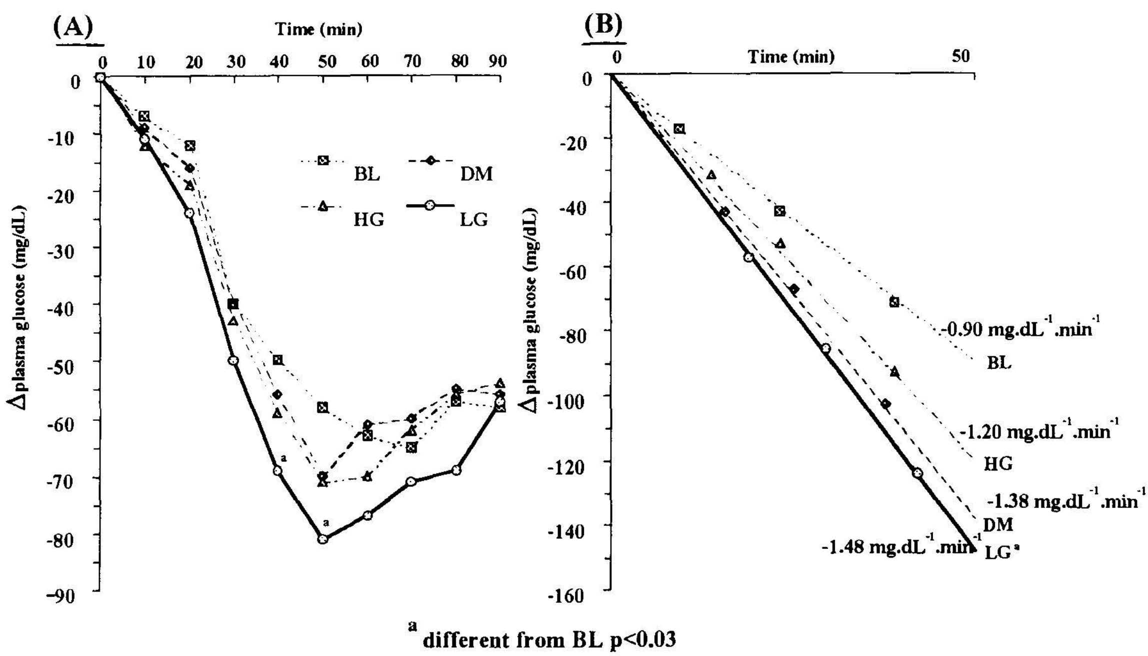

Fig. 4. Comparison of Δplasma glucose (A) and slope of plasma glucose (B) responses to a bolus of insulin injection after 4 wks on diets with various glycemic indices.

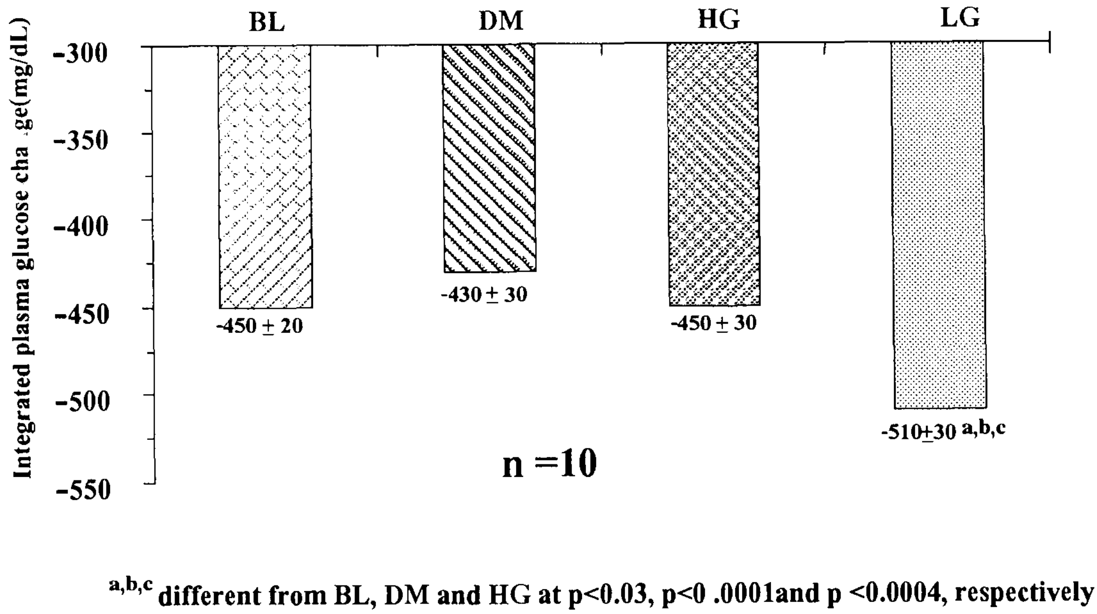

Fig. 5. **Comparison of integrated plasma glucose decrements responding to a bolus of intravenous insulin injection (0.8 μ/kg) after 4 wks on diets with various glycemic indices.**

HG and LG occurred at 50 min. after insulin injection, whereas, that of BL did not occur until 70 min. after insulin injection. The response of plasma glucose levels at 40 and 50 min. after insulin injection were significantly lower during LG compared to BL. Long-term LG ingestion produced a significantly steeper slope than ingestion of BL (Fig. 4B). There was no difference among glucose reduction slopes of other diets. Integrated plasma glucose reduction responding to insulin injection was significantly greater during LG than during all other diets (Fig. 5). There was no difference among other diets.

The mean HbA1 levels and urinary glucose levels during LG, DM and HG were significantly lower than during BL but there was no significant difference (Fig. 6 and 7). LG excreted significantly higher urinary creatinine than BL and DM (Fig. 8). Urinary nitrogen during LG was significantly lower than that measured during BL and HG, respectively (Fig. 8). There were no significant differences among the mean nitrogen balances during BL, DM and HG but LG produced significantly positive nitrogen balance which was significantly better than BL and HG.

DISCUSSION

Most of our subjects had android obesity with a mean waist to hip ratio of 0.93 ± 0.01 which, according to Vague(12), carries greater risk of metabolic complications than gynoid obesity. These abnormal profiles were not improved with any diet. There was an insignificant drop of about 3 per cent in the body weight, BMI and the per cent body fat during DM (as the representative of good dietary control) compared to BL (Fig. 1). This could be due to the effect of strict dietary control. However, there was no difference in these parameters among all test-diets implying that our subjects consumed consistent energy intake throughout the study. Staying on different study-diets did not alter the hematological status (Table 3), serum albumin and serum urea nitrogen while serum creatinine increased during LG implying that a normal muscle mass was maintained(13) during LG. In this study, no persistent statistical difference in the diurnal plasma glucose levels or integrated plasma glucose levels among diets were found though LG seemed to produce lower diurnal glucose levels than the others (Fig. 2A, 3A). However, the DM diet was lower than BL in

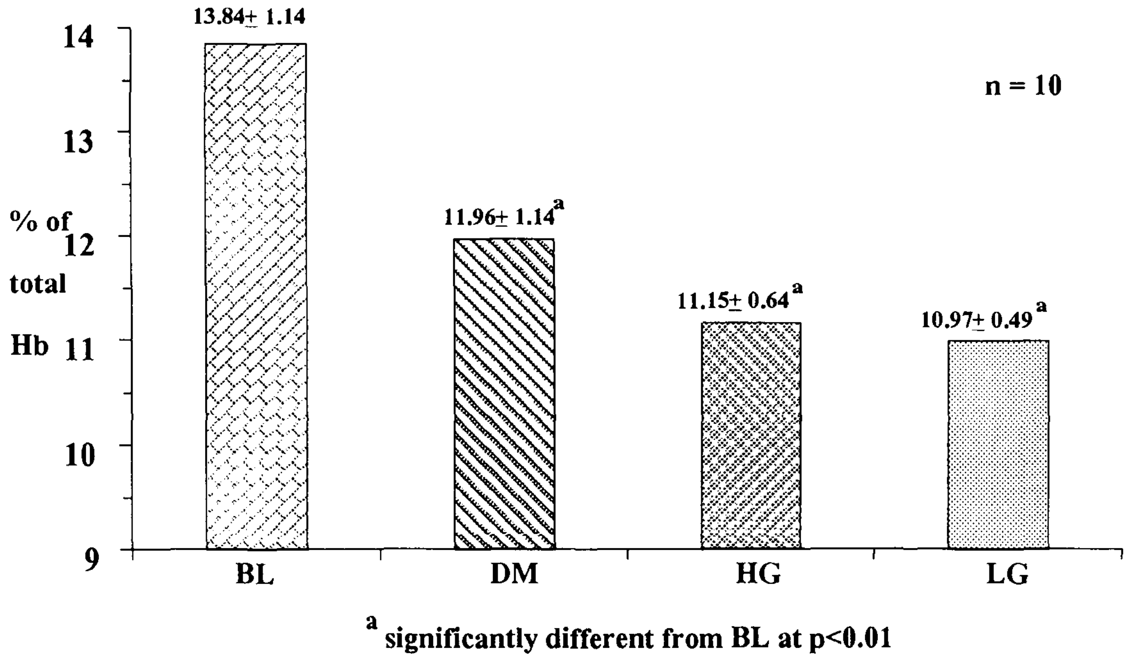

Fig. 6. Comparison of HbA_1 after 4 wks on diets with various glycemic indices.

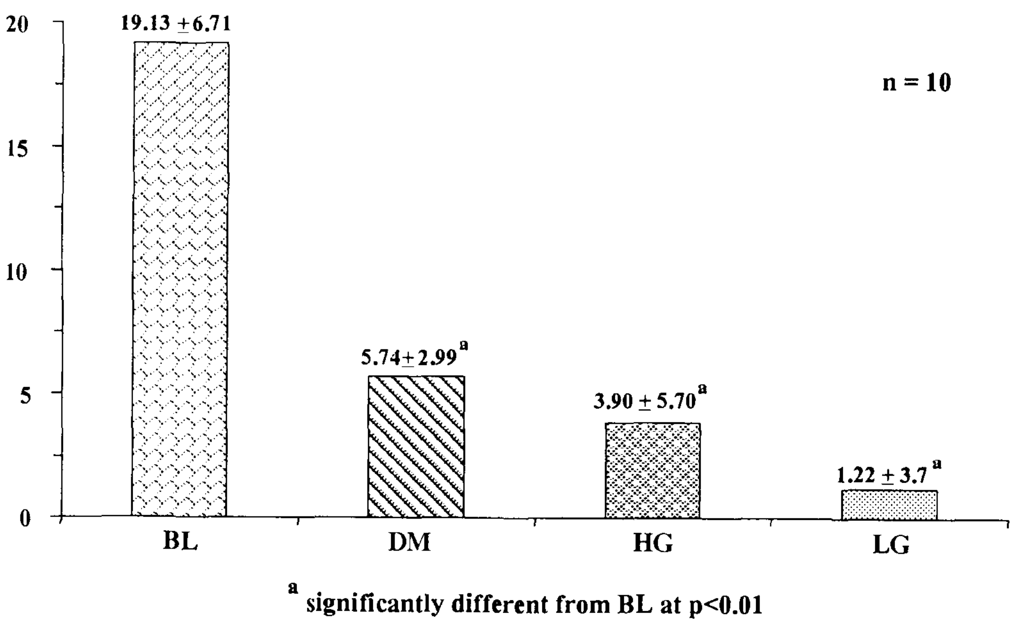

Fig. 7. Urinary glucose excretion after 4 wks on diets with various glycemic indices.

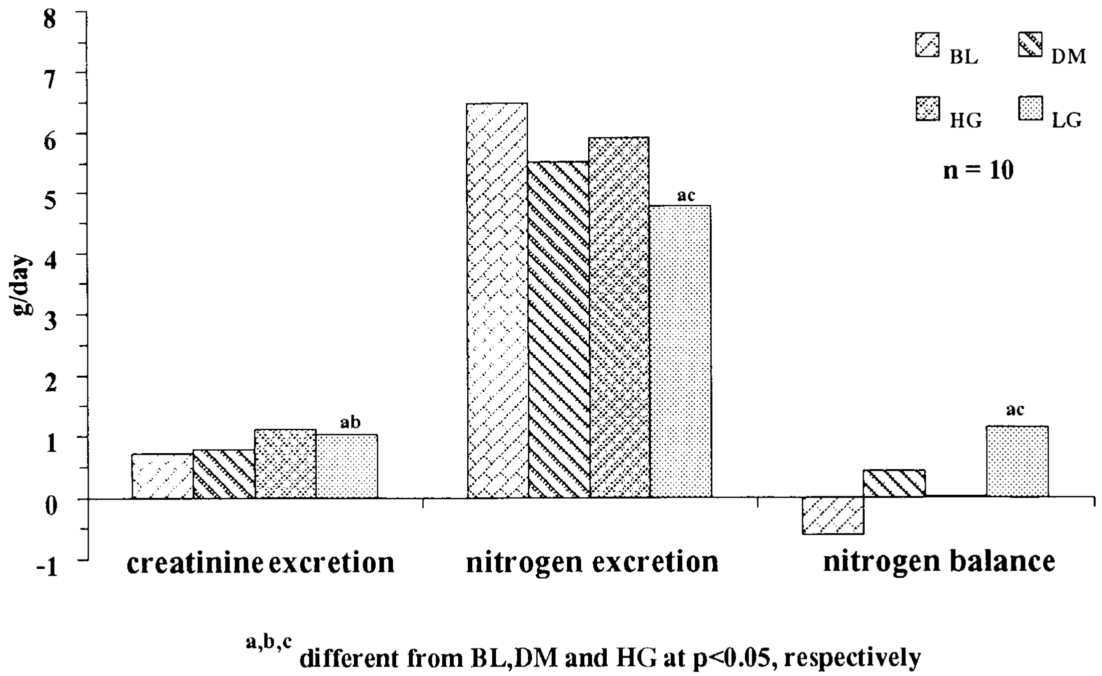

Fig. 8. Comparison of urinary creatinine excretion, nitrogen excretion and nitrogen balance after 4 wks on diets with various glycemic indices.

several insulin measurements as well as the integrated insulin levels during the nine hours of observation (Fig. 2B, 3B). This implies that good dietary control plays a significant role in unloading stress on the pancreas by modulating the glucose absorption and plasma glucose resulting in reduced insulin response. This was due to the combination of the glycemic effect of rice (GI = 100), the effect of dietary fibers(5) and good dietary control(14) since our subjects were individually taught, actually practiced and were closely followed-up during the study period. This improvement during DM could also be partly due to increased insulin receptors after weight reduction(15) which lead to a lower insulin demand. LG also showed a plasma insulin response similar to DM but lower plasma glucose than DM.

Though a high-carbohydrate, high-fiber diet has been shown to reduce the glycemic response, the differences seen in our study among LG and other study-diets were not attributed to the effect of dietary fiber since subjects consumed the same amount of fibers during different dietary periods. These data point to the significance of the LG diet itself in modulating the glucose response without relying on the amount of fibers since mungbean-noodles representing our LG product contained a negligible amount of fiber (0.46%)(16). The integrated plasma insulin levels were lower during DM and LG compared to HG rendering the glucose modulating effect of fiber less significant. It is not surprising to see similar integrated plasma glucose levels between DM (represented by rice) and HG (represented by glutinous rice) since their glycemic indices are 100 and 106, respectively. LG represented by mungbean noodles and rice noodles which have a GI of 63 and 76, respectively. The main difference in glycemic effect among mungbean noodles, rice and glutinous rice seems to lie on their amylose content which was 37-46 per cent, 15-18 per cent and 1-2 per cent, respectively (17). Since high amylose rice delays digestion and/or absorption of carbohydrate[18] it causes a lower initial response and slower decline in both glucose and insulin levels[19]. These results rely on the process of hydrolyzing the amylose in the gastrointestinal tract. After being partially digested by salivary and pancreatic amylases, the remaining oligosaccharides will be further digested by α-glucosidase at 1, 4 bonds of the straight and branch-chained units only, whereas, the amylopectin can also be digested by α-dextrinase as well[20]. Furthermore, the higher degree of retrogradation during the manufacturing process of mungbean noodles retards carbohydrate digestion[21]. The steeper slope of plasma glucose response to insulin during long-term LG than BL (Fig. 4B) reflects the greater response of glucose metabolism to insulin when subjects were fed with a low glycemic diet (mungbean noodles) for a long period. The maximum effect of insulin, shown by the nadir of plasma glucose, was reached sooner (50 *vs* 70 min.) when subjects were on DM, HG and LG compared to BL (Fig. 4A). The 24-hour urinary glucose decreased during the long-term ingestion of the test-diets, however, the lowest level was observed during LG which was in accord with previous reports[19]. HbA_1, an indicator of long-term glucose control of diabetes[22], was also decreased during long-term consumption of various diets compared to BL.

Though LG produced the lowest glycated Hb, we did not find significant difference among DM, HG and LG. This may be due to firstly, the small glycemic differences among the food particularly after a big reduction of glucose had already occurred as a result of good dietary management while on the DM diet and secondly, inadequate time on each diet (only 4 wks). However, only LG could produce significant reduction of urinary nitrogen and significant improvement of nitrogen balance and urinary creatinine. This can be explained by the improvement of insulin sensitivity caused by LG. It is concluded that improved carbohydrate metabolism reduces hyperglycemia leading to a reduction of glucosuria and glycated hemoglobin. More importantly, when insulin is insufficient, increased protein catabolism, increased gluconeogenesis and increased urinary nitrogen excretion occur[23,1,2]. These findings agree with the findings by Gougeon et al[1], which reflect the inability to maintain an anabolic process with a poorly controlled diet, BL. Hence, muscle catabolism occurred, followed by reduction of muscle mass and reduced urinary creatinine[24]. After consumption of ADA diets (all study-diets), better insulin sensitivity, less urinary nitrogen excretion with an improved nitrogen balance and more urinary creatinine excretion were observed but only the mungbean noodle diet produced significant improvement from BL. These results explain why the subjects had normal visceral protein and increased creatinine (reflections of more muscle mass) while they were on LG. Although, good dietary control is essential, selection of good quality carbohydrates provides remarkable benefit since it leads not only to good glucose control but also to more anabolic process, more muscle mass and overall improvement of body metabolism.

In conclusion, our study showed that during strict dietary control even as out-patients a better control of plasma glucose was evident by decreased urinary glucose, nitrogen excretion, insulin secretion and also the glycosylated hemoglobin levels. Long-term dietary control improved the insulin response (sensitivity). Glutinous or sticky rice may produce an adverse outcome since it stimulated more insulin secretion but this adverse effect could be modulated by the effect of good dietary management. Mungbean-noodles used in this study, without effect of increased dietary fiber, improved long-term glycemic control, increased insulin responsiveness, reduced insulin secretion and improved nitrogen balance and encouraged anabolism in diabetes.

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ผลของการรับประทานอาหารเอเชียที่มีดัชนีน้ำตาลต่าง ๆ เป็นระยะเวลานานต่อการควบคุมเบาหวานและสงวนโปรตีนในผู้ป่วยเบาหวานชนิดที่ 2

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ได้ทำการศึกษาในผู้ป่วยหญิงที่เป็นเบาหวานชนิดที่ 2 จำนวน 10 คน อายุระหว่าง 32-60 ปี ผู้ป่วยได้รับอาหารเบาหวานที่ถูกจัดให้เพื่อคงน้ำหนักโดยมีการกระจายของพลังงานให้ได้จากโปรตีน ไขมัน เป็นร้อยละ 12, 30 และจากคาร์โบไฮเดรตเป็นร้อยละ 58 ของพลังงานทั้งหมด ความแตกต่างของอาหารที่ทดลองขึ้นอยู่กับชนิดของคาร์โบไฮเดรตเชิงซ้อน อาหารเบาหวานที่มีดัชนีน้ำตาลสูงหรือดัชนีน้ำตาลต่ำประกอบด้วยข้าวเหนียวหรือวุ้นเส้นเป็นหลัก อาหารเบาหวานที่มีดัชนีน้ำตาลระดับปานกลาง ประกอบด้วยข้าวจ้าวเพียงอย่างเดียว หลังจากศึกษาผลของอาหารพื้นฐานแล้ว ผู้ป่วยแต่ละคนถูกจัดให้กินอาหารเบาหวาน (ดัชนีน้ำตาลปานกลาง) ตามด้วยอาหารดัชนีน้ำตาลสูงหรือต่ำแล้วแต่จับฉลากได้ โดยกินชนิดละ 4 สัปดาห์ พบว่า ระดับของน้ำตาลในเลือดตลอดวันหลังจากกินวุ้นเส้นมีแนวโน้มลดลงต่ำกว่าชนิดอื่น แต่ค่ารวมของระดับน้ำตาลในเลือดตลอดวันของแต่ละอาหารไม่แตกต่างกัน ค่ารวมของระดับอินสุลินในเลือดตลอดวันหลังจากกินอาหารเบาหวานที่มีดัชนีน้ำตาลปานกลางและอาหารดัชนีน้ำตาลต่ำไม่แตกต่างกัน แต่ทั้งสองค่าต่ำกว่าเมื่อกินอาหารที่มีดัชนีน้ำตาลสูงและอาหารพื้นฐานอย่างมีนัยสำคัญทางสถิติ พบว่า การควบคุมโดยการกินอาหารเบาหวานที่มีดัชนีน้ำตาลทุกชนิดเป็นระยะเวลานาน สามารถลดปริมาณน้ำตาลที่ล้นออกมาในปัสสาวะตลอด 24 ชั่วโมงลงกว่าการกินอาหารพื้นฐานอย่างมีนัยสำคัญ โดยอาหารที่มีดัชนีน้ำตาลต่ำจะมีน้ำตาลล้นออกน้อยที่สุด ระดับของฮีโมโกลบินเอหนึ่ง (HbA_1) และดุลไนโตรเจนดีขึ้นอย่างมีนัยสำคัญหลังจากกินอาหารเบาหวานชนิดต่าง ๆ เมื่อเทียบกับอาหารพื้นฐาน โดยอาหารดัชนีน้ำตาลต่ำให้ผลดีที่สุด แสดงให้เห็นว่านอกจากการปฏิบัติตัวอย่างเคร่งครัดของผู้ป่วยแล้ว การกินวุ้นเส้นแท้ (อาหารที่มีดัชนีน้ำตาลต่ำ) โดยไม่ต้องเพิ่มใยอาหาร ก็สามารถช่วยให้การควบคุมเบาหวานและการสงวนโปรตีนของร่างกายดีขึ้น

คำสำคัญ : อาหารเบาหวาน, วุ้นเส้น, ดัชนีน้ำตาล, ข้าวเหนียว, ข้าว

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