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Responses of blood glucose and C-peptide to five Chinese starchy foods

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Forty-nine patients with non-insulin-dependent diabetes mellitus (NIDDM) were randomly divided into four groups (10–18 patients per group) to compare the responses of blood glucose and C-peptide to some Chinese starchy foods. Ten healthy subjects were used as controls. After an overnight fast, the blood samples were drawn at fasting and 30, 60, 120, 180 minutes postprandially to measure plasma glucose and serum C-peptide levels. Bun, which was made from refined wheat flour and similar to white bread, was used in the assessment as the reference food. Other test foods included rice, lotus seed, seed of gordon euryale, and rhizome of common yam. There was only one kind of food in each test meal, and each serving contained 50 g of carbohydrate. With both glycaemic index (GI) and C-peptide index (CI) of bun set as 100 in this study, the GI and CI respectively were: rice 89 and 91; lotus seed 62 and 72; seed of gordon euryale 102 and 102; rhizome of common yam 103 and 95. The GI and CI of lotus seed were significantly lower than those of other test foods. It appears that lotus seed may have a beneficial effect in NIDDM patients, and may be one of the more appropriate foods for diabetic patients.

Introduction

With the liberalization of carbohydrate intake in diabetic patients, many studies have focused on postprandial glycaemic responses to carbohydrate-rich foods. It is known that different foods with the same amount of carbohydrate may produce difference glycaemic responses[1–7]. The glycaemic index, an indicator of post-prandial glycaemic response to food, is widely used in conjunction with the diabetes exchange list in planning diabetic diets, especially in selecting starchy foods.

Some Chinese starchy foods (eg lotus seed, seed of gordon euryale, rhizome of common yam etc.), according to traditional Chinese Medicine, are regarded as both edible foods and effective herbal medicines for diabetes, and have been recommended in China as alternative staple foods for diabetics. On the other hand, bun and rice are two main staple foods in China. Whether any of these foods can produce a lower glycaemic response needs to be determined. In this study we observed the blood glucose and C-peptide responses to these Chinese starchy foods in diabetic and healthy subjects, in order to determine which of these foods is more appropriate for inclusion in a diabetic diet.

Subjects and methods

Subjects included 49 volunteer non-insulin-dependent diabetes mellitus (NIDDM) patients (25 male and 24 female) and ten healthy volunteers (five male and five female). The age of the subjects, the body mass index (BMI), the fasting plasma glucose level and daily therapy are shown in Table 1.

Ethics statement

The patients were randomly divided into four groups (10–18 patients per group), while all the healthy persons comprised a single control group. The studies were conducted on two mornings in NIDDM patients and three mornings in healthy subjects. After a 10- hour overnight fast, an intravenous cannula was placed in the forearm vein of the subject. A test meal was consumed within 15 minutes. The test meal was bun for all groups on the first test morning and either rice (*Oryza sativa* subsp. hsien), lotus seed (*Nelumbo nucifera*), seed of gordon euryale (*Euryale ferox*) or rhizome of common yam (*Dioscorea opposita*) for each test group, on the second test morning in NIDDM subjects. For healthy subjects the test meal was also bun on the first test morning, rice on the second, and lotus seed on the third. Among these five test foods, bun (which was made from refined wheat flour and similar to white bread), was served as the reference foods. The other foods (rice, lotus seed, seed of gordon euryale, and rhizome of common yam) were prepared by steaming in some water and a little salt until soft. Each serving consisted of only one kind of test food and contained 50 grams of carbohydrate. Table 2 shows the composition of the test foods.

During the test morning, all subjects rested and consumed no extra foods, but took a sip of water once in a while. Neither oral hypoglycaemic agents nor regular insulin was used in NIDDM subjects. Blood samples were drawn at fasting and after 30, 60, 120, 180 minutes post-prandially via intravenous cannula, for measuring glucose and C-peptide levels. Plasma glucose was determined using the glucose oxidase method

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Table 1. Characteristics of NIDDM and healthy subjects: values are means ± sd.

Subjects	Mean age (range) (years)	Mean BMI (range) (kg/m^2)	fasting plasma glucose (mmol/l)	Daily therapy
NIDDM	52 ± 8 (28–65)	21.68 ± 2.44 (14.28–26.34)	9.98 ± 3.62	Diet, oral hypoglycaemic agents,and/or regular insulin
Healthy	47 ± 10 (35–61)	22.40 ± 0.97 (16.65–26.99)	4.90 ± 0.45	None
P	> 0.05	> 0.05	< 0.05	

Table 2. The Composition of test foods[a].

Test Foods	Raw weight (g)	Protein (g)	Fat (g)	Carbohydrate (g)	Dietary fibre (g)
Bun[b]	67	6.90	0.74	50	0.40
Rice	65	5.40	0.65	50	0.33
Lotus seed	78	13.40	1.56	50	2.34
Seed of gordon euryale	69	6.66	0.14	50	1.04
Rhizome of common yam	72	6.77	0.72	50	1.01

[a] Values from Food Composition Tables, China, published in 1991.
[b] Weight of refined wheat flour.

and serum C-peptide using the radioimmunoassay method (DPC kits). The equation of Wolever[8] was used to calculate the glycaemic index. The C-peptide index was calculated using a similar method.

$$\text{Glycaemic index} = \frac{\text{Incremental area under blood glucose response curve for test food}}{\text{Corresponding area after equicarbohydrate portion of reference food}} \times 100$$

Data were expressed as mean±SE. Incremental areas under the glucose or C-peptide responses curves were calculated geometrically. Paired or unpaired data were assessed by T-test. Multiple comparisons were made by ANOVA, and a possible association between glyceamic index and C-peptide index was tested using a correlation analysis. The level of statistical significance was set at 0.05.

Results

It appeared that the glycaemic index and C-peptide index of the same starchy food were not significantly different between NIDDM and healthy subjects ($P>0.05$, Table 3). For this reason, the results of NIDDM and healthy subjects were combined. The glycaemic indexes and C-peptide indexes of the test foods in NIDDM and healthy subjects were then calculated for the group as a whole (Table 4).

Among the five starchy foods tested, the glycaemic index of lotus seed was significantly lower than that of rice ($t=3.42$, $P<0.01$), seed of gordon euryale ($t=4.37$, $P<0.001$) and rhizome of common yam ($t=4.23$, $P<0.001$). The glycaemic indexes of the latter three foods were not different statistically ($F=1.48$, $P>0.05$). Also the C-peptide index of lotus seed was significantly lower than that of rice ($t=2.11$, $P<0.05$) and seed of gordon euryale ($t=2.49$, $P<0.05$), but not rhizome of common yam ($t=1.89$, $P>0.05$). The C-peptide indexes of rice, seed of gordon euryale and rhizome of common yam were not different statistically ($F=0.49$, $P>0.05$).

Table 3. Comparison of glycaemic index and C-peptide index between NIDDM and healthy subjects.

Test foods	Glycaemic index		C-peptide index	
	NIDDM(n1)	Healthy (n2)	NIDDM(n1)	Healthy (n2)
Rice	87.50±6.17	91.00±10.31	91.46±8.77	89.90±8.34
	(n1=18,n2=10, t=0.31, p=0.76)		(n1=13, n2=10, t=0.13, p=0.90)	
Lotus seed	72.00±7.78	52.70±6.13	73.80±12.26	70.90±4.29
	(n1=10, n2=10, t=1.95, p=0.07)		(n1=10, n2=10, t=0.22, p=0.83)	

Table 4. Glycaemic indexes and C-peptide indexes of five Chinese starchy foods.

Test foods	Glycaemic index (case)	C-peptide index (case)
Bun[a]	100	100
Rice[b]	88.75±5.31[b](28)	90.78±6.01[b](23)
Lotus seed[b]	62.35±5.30[a](20)	72.35±6.33[a](20)
Seed of gordon euryale[c]	101.73±7.39[b](11)	101.90±11.05[b](10)
rhizome of common yam[c]	102.60±8.30[b](10)	95.00±8.98[a,b](7)

[a] Reference food: glycaemic index and C-peptide index set at 100.
[b] Pool of NIDDM and healthy subjects.
[c] Group of NIDDM subjects.
Different superscript letters in the same column showed the figures were significantly different at $P<0.05$.

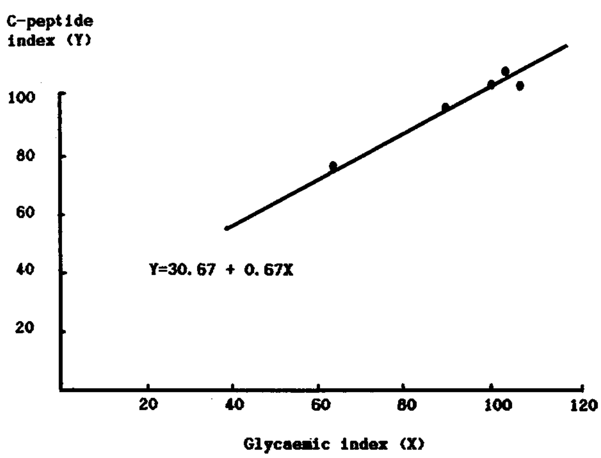

Figure 1. Linear relationship between glycaemic indexes and c-peptide indexes in five Chinese starchy foods.

There was a significant linear correlation ($t=6.78$, $P<0.01$, see Figure 1) between the glycaemic indexes and C-peptide indexes. The correlation coefficient was 0.97.

When the blood glucose (or C-peptide) response to bun was compaired with that of rice, it was appropriate to compare the incremental area under the blood glucose (or C-peptide) response curve instead of glycaemic index (or C-peptide index), because the glycaemic index (or C-peptide index) of bun was a reference value not a mean. In this study we performed pairwise comparisons between the incremental areas under the blood glucose response curves (IAG) of bun with those of rice in NIDDM patients. There was no significant difference between those of rice and bun ($t=1.74$, $P>0.05$), but the incremental areas under the blood C-peptide response curves (IAC) of rice were lower than those of bun ($t=2.32$, $P<0.05$). See Table 5.

Table 5. Pairwise comparisons between the incremental areas under the blood glucose (or C-peptide) response curves of bun and rice in NIDDM subjects.

Test foods	IAG (mmol.h/l, $n=18$)	IAC (pmol.h/l, $n=13$)
Bun	14.31±0.93	1.18±0.21
Rice	12.67±1.00	0.91±0.14
P	> 0.05	< 0.05

Discussion

These results demonstrate that different kinds of starch-rich foods with an equal carbohydrate content might produce different blood glucose and C-peptide responses. Glycaemic indexes (GI), which represented the postprandial glycaemic responses of foods, were valuable parameters. Foods with lower postprandial glycaemic responses usually also showed lower glycaemic indexes. On the other hand, C-peptide indexes (CI), which represented the post-prandial insulin secretory responses, always varied in concert with the glycaemic indexes in both NIDDM and healthy persons. There was a positive correlation between GI and CI, ie foods with a high glycaemic index appeared to have a high C-peptide index, and vice versa. This suggests that among foods with the same macronutrient composition, those with low glycaemic indexes and C-peptide indexes might be better for diabetic patients than those with high indexes.

Our results also demonstrated that the glycaemic index and C-peptide index of the same starchy food were not significantly different between NIDDM and healthy subjects, but there were obvious individual variations for both indexes. These results are comparable with those of the previous report[8]. Thus the glycaemic indexes and C-peptide indexes measured in normals were comparable for NIDDM patients. When we plan a meal for diabetes, not only the glycaemic indexes and C-peptide indexes of foods but also the individual variations should be considered.

As Chinese main staple foods, bun is common in the north and rice in the south. Using pairwise comparisons for bun and rice, we did not find any difference between the incremental areas under the blood glucose response curves in NIDDM patients. This suggests that rice is not superior to bun for a diabetic diet. This result was consistent with the previous result in healthy Chinese[7]. Perhaps some kinds of rice with a high portion of amylose might produce a low glycaemic response[9], but in our study we did not analyse amylose content of the rice.

According to traditional Chinese medicine, some foods with herbal characteristics, for example, lotus seed, seed of gordon euryale and rhizome of common yam, are deemed to be the equivalent of herbs and are thought to invigorate the digestive organs. They can be used as therapeutic foods for diabetes[10,11]. In our study, lotus seed showed a lower glycaemic index and C-peptide index than the other foods tested, but these indexes did not differ between seed of gordon euryale, rhizomes of common yam and rice. This suggests that lotus seed may be more suitable food for diabetic patients.

Growing in most parts of the south of China, lotus seed is commonly used in soup, congee and dessert. Sweet minced lotus seed is also widely used in buns, bread and cake in China. According to Chinese food composition analyses, lotus seed is rich in carbohydrate (64.2%), protein (17.2%) and kalium (846mg/100g), but low in fat (2.0%). Its dietary fibre is about 3%[12]. All of these factors may confer some advantages of lotus seed over other foods for diabetic patients. Lotus seed is, however, limited in methionine[12], so it is better to consume lotus seed with some methionine-rich foods.

As we know, there are many factors that affect the postprandial glycaemic responses of foods, including: the nature of the starch; dietary fibre content; food form; particle size; cooking method; antinutrients (eg lectins, phytates, saponins, tannins and enzyme inhibitors); as well as starch-protein and starch-lipid interactions etc[8, 13]. Whether lotus seed gave a low postprandial glycaemic response due to a high amylose content, due to the presence of some unknown material, needs further investigation.

Conclusion

Different kinds of starchy foods may produce various postprandial glycaemic responses. Lotus seed appears to produce both glycaemic and C-peptide lower responses, and may have a beneficial effect on diabetes. Our study, however, on single foods, how lotus seed acts in a mixed Chinese meal will require further study.

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中国五种淀粉类食物的餐后血糖和C肽反应

摘 要

作者将49例非胰岛素依赖型糖尿病(NIDDM)病人随机分成4组，每组10–18人，以10名健康人作对照，收集上述研究对象空腹及进食实验食物餐后30、60、120、180分钟的血液样本，作血浆葡萄糖和血清C肽的测定。实验食物包括馒头、米饭、莲子、芡实和淮山（每份食物含碳水化物50克），其中馒头作为参照食物标准，其血糖指数和C肽指数均定作100，其余实验食物的血糖指数和C肽指数分别是，米饭89，91；莲子62，72；芡实102，102；淮山103，95。结果表明，莲子的血糖指数和C肽指数均明显较低。在五种实验食物中，莲子在控制餐后血糖和胰岛素水平方面的作用最好，可作为糖尿病饮食治疗的一种首选食物。