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Improved Glucose Tolerance Four Hours after Taking Guar with Glucose

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Summary. To gain some insights about the possible cumulative metabolic effect after a high-fibre meal, 6 subjects took two 80 g oral glucose loads, 4 h apart. Addition of 22.3 g guar to the first load decreased the rise in blood glucose and insulin after the second (guar-free) load by 50% ($p < 0.002$) and 31% ($p < 0.02$) respectively. This corresponded with decreased 3-hydroxybutyrate levels at the start of the glucose tolerance test after guar (by 20%, $p < 0.02$). When no guar was added to the first glucose load, both 3-hydroxybutyrate and non-esterified fatty acids tended to rise before the second test. No significant effect was seen in the responses of the gut hormones, gastric inhibitory peptide and enteroglucagon. Spreading the intake of the first 80 g of glucose over the initial 4 h (2 subjects) similarly flattened the glycaemic but increased the insulin response. The effect of guar on carbohydrate and fat metabolism, therefore, lasts at least 4 h and may result in improved carbohydrate tolerance to subsequent guar-free meals.

Key words: Dietary fibre, guar, glucose tolerance.

Recent work has suggested that high-fibre diets can be of great benefit to diabetics by reducing fasting blood glucose and lipid levels [1], decreasing postprandial glycaemia [2–4], reducing 24-hour urinary glucose output [5] and allowing withdrawal of insulin or decrease in dosage [1].

The exact mechanisms are unknown. It has been suggested that dietary fibre may slow the rate of absorption of glucose. This would allow substrate entry into the blood to be matched more closely by uptake in liver and peripheral tissues [2] and so, for example, flatten postprandial glycaemia. In support of this hypothesis, certain types of unabsorbable carbohydrate (dietary fibre) reduce the rate of gastric emptying [6] and delay mouth-to-caecum transit time [7], xylose absorption [7], and glucose diffusion (unpublished data).

However, all these findings are related to the interaction of dietary fibre with food in the gastrointestinal tract. None explains the cumulative metabolic effect of dietary fibre which may allow gradual reduction and even withdrawal of insulin for some non-insulin dependent diabetics [1].

To see whether the effects of taking one fibre-rich meal might persist long enough to alter the glucose response to a subsequent fibre-free meal, we have looked at the glucose response to an 80 g glucose drink taken 4 hours after a similar glucose drink which on one occasion was supplemented with guar.

Subjects and Methods

On two separate occasions, after overnight fasts (10–14 h), 6 non-diabetic volunteers (5 male, 1 female; 27 ± 4 y; 104 ± 2% desirable weight [8]), took 2 glucose drinks separated by a 4-h interval. Each drink contained 80 g glucose in 800 ml water flavoured with 64 g pure lemon juice (PLJ Original Sharp, Beecham Products, Brentford, Middlesex). The drinks were taken at an even rate, the first over 20 min and the second over 3 min. On one of the two days, 22.3 g guar (Hercules Powder Co., Erith, Kent) was added to the first glucose drink to gel the solution, which was the reason why 20 min was allowed for consumption of the first glucose load. Two subjects also underwent a further experiment where the first (guar-free) glucose drink was taken as 50 ml aliquots once every 15 min over the 4 h prior to the GTT. Venous blood samples were taken fasting, before the first glucose drink, and at 0, 15, 30, 45, 60, 90 and 120 min after the start of the GTT for the measurement of blood glucose [9], plasma non-esterified fatty acids (NEFA) [10], blood 3-hydroxybutyrate [11], serum insulin [12], plasma enteroglucagon [13], and gastric inhibitory peptide (GIP) [14].

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Table 1. Blood 3-hydroxybutyrate levels in six healthy subjects before taking 80 g glucose (control) or 80 g glucose and 22.3 g guar (test) and followed in both instances at 4 hours by an 80 g GTT (0–120 min). Time 0 = 4 hours after first load

	Blood 3-hydroxybutyrate μmol/l														
	Control Time in minutes							Test Time in minutes							
Subject	Fasting	0	15	30	45	60	90	120	Fasting	0	15	30	45	60	90	120
1	128	279	286	153	61	36	25	20	56	39	36	45	24	28	18	24
2	24	23	17	19	18	23	24	19	21	15	22	20	19	17	14	24
3	44	50	54	49	44	42	49	49	82	54	54	50	49	39	45	49
4	46	139	153	95	13	39	39	44	49	46	62	61	43	39	30	43
5	23	19	21	17	23	16	17	13	32	26	29	27	21	14	17	26
6	66	107	109	82	57	50	35	33	32	32	33	29	25	27	28	32
Mean	55	103	107	69	40	34	32	30	45	35	39	39	30	27	25	32
± SEM	±16	±40	±42	±21	±7	±5	±5	±6	±9	±6	±6	±6	±5	±4	±5	±5

Table 2. Plasma non-esterified fatty acid (NEFA) levels in five healthy subjects before taking 80 g glucose (control) or 80 g glucose and 22.3 g guar (test), and 4 hours later prior to an 80 g GTT (0 min). Time 0 = 4 hours after first load

	Plasma NEFA μmol/l			
	Control		Test	
Subject	Fasting	0 min	Fasting	0 min
1	780	1623	767	906
2	497	497	516	428
3	419	195	471	133
4	336	326	762	371
6	663	1100	474	353
Mean	539	748	598	438
± SEM	±81	±245	±62	±116

The study was approved by the Oxfordshire Area Health Authority Ethical Committee. The results are expressed as mean ± SEM and significance of the differences were calculated using Student's t-test for paired data.

Results

All meals were taken over the allotted time although due to the viscosity of the guar three of the subjects found the large volume unpalatable. Their results did not differ from the other three subjects who found it acceptable. The initial pre-test fasting glucose and insulin values were 4.7 ± 0.1 mmol/l and 49 ± 9 pmol/l respectively and had fallen significantly by 0.5 ± 0.15 mmol/l ($p < 0.05$) and 13 ± 4 pmol/l ($p < 0.02$) by 4 hours after the first guar-free glucose load. Addition of guar to the first drink abolished these differences. By 4 hours after the first guar-free glucose load, there was a non-significant rise of 59 ± 31% in 3-hydroxybutyrate levels from a fasting value of 55 ± 16 μmol/l (Table 1). However, addition of guar resulted in a fall of 20 ± 8% in 3-hydroxybutyrate levels ($p < 0.02$) from a fasting value of 45 ± 9 μmol/l. Due to the scatter of the starting values, no significant change in absolute figures was seen. A similar trend was seen in the 5 subjects on whom plasma NEFA measurements were made (Table 2). After the first control drink, there was a tendency for the NEFA level to rise from the fasting value of 539 ± 81 μmol/l by 24 ± 28%, while after guar there was a fall from 598 ± 64 mmol/l by 30 ± 15%. Although these changes were not significant in themselves, if the percentage control change is subtracted from that after guar, to give the relative change after guar, a fall of 53 ± 17% was seen ($p < 0.05$).

No effect was seen on plasma GIP or enteroglucagon levels. When guar was used to thicken the first drink, the glucose and insulin rises were much less marked after the second glucose load (Fig. 1). The decrease in area under the glucose curve was 50% ($p < 0.002$), and under the insulin curve 31% ($p < 0.02$).

No significant difference was seen in GIP (Fig. 1) or enteroglucagon levels when the GTT followed guar.

In the 2 subjects who took the first glucose drink spread over 4 hours, there was only a small rise in blood glucose after the glucose tolerance test. However, the 4-hour glucose level was already elevated (Fig. 2), while the initial 4-hour changes in 3-hydroxybutyrate were similar to those seen after guar. The insulin response, however, was greater than after guar (Fig. 2). Again, no difference was seen in the GIP (Fig. 2), or the enteroglucagon responses.

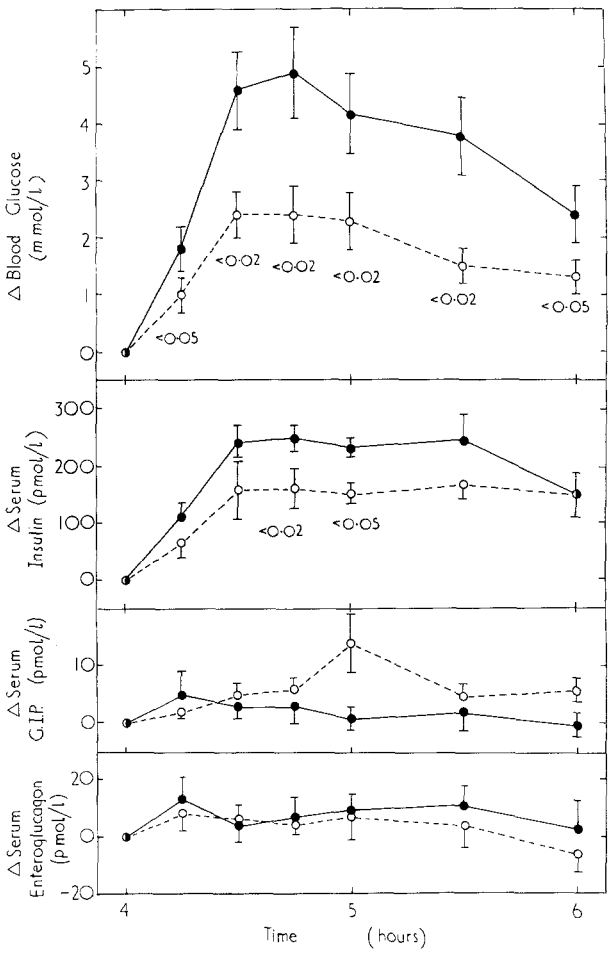

Fig. 1. Mean rises in blood glucose, serum insulin, gastric inhibitory peptide (G. I. P.), and enteroglucagon levels in 6 subjects after the second of two 80 g glucose drinks with or without 22.3 g guar added to the first drink (guar O------O, control ●——●)

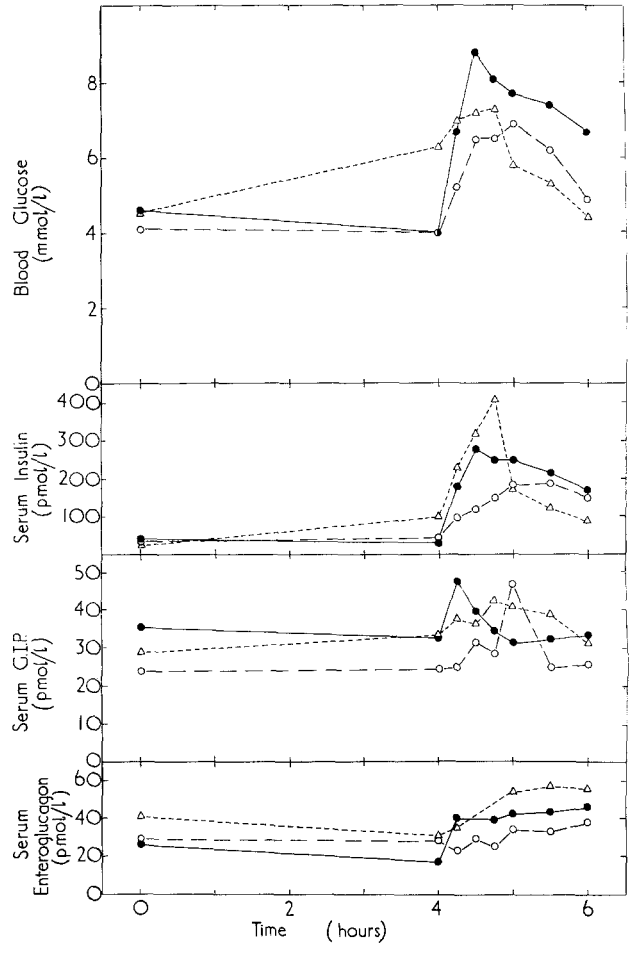

Fig. 2. Mean blood glucose, serum insulin, gastric inhibitory peptide (GIP) and enteroglucagon levels in 2 subjects who took two 80 g glucose drinks with or without 22.3 g guar added to the first drink (guar O---O, control ●——●) or after continuous sipping of the first (guar-free) 80 g glucose drink over 4 hours (△------△)

Discussion

The results show that when 2 glucose drinks were taken 4 hours apart, addition of guar to the first markedly flattened the rise in blood glucose after the subsequent guar-free drink. This difference was not due to increased levels of insulin nor was there any accompanying change in GIP or enteroglucagon levels. In previous studies physical interaction of guar and glucose provides the explanation for the reduced glucose peak after meals in diabetic patients [3] and control subjects [2]. A similar mechanism is unlikely here since it is improbable that sufficient guar remained in the gut to alter viscosity. In support of this, when 14.5 g guar was given, as little as 2 minutes before taking a 50 g glucose drink, no effect was seen on the subsequent glucose tolerance and it was concluded that the action of guar in flattening the postprandial rise in blood glucose depended on intimate mixing which allowed the guar to impede glucose uptake and so prolong the time over which glucose was absorbed [15].

The present results suggest that slow absorption of carbohydrate after guar may result in sustained alterations in glucose handling, perhaps dependent upon altered hepatic or peripheral tissue metabolism. The metabolic consequences of this could be additive and eventually predominate in the long-term action of these substances. This action may, therefore, be summarized as a reduction of the oscillations in metabolite and hormonal responses. Thus the flattened postprandial glycaemia and decreased insulin levels would lessen the tendency of the blood glucose to 'undershoot' the fasting value and so, for example, decrease the stimulus to ketone body and non-

esterified fatty acid release. Glucose might then be taken up more readily by peripheral tissues.

In the studies reported here, there was a tendency for 3-hydroxybutyrate levels to rise after the first control glucose drink. Those whose starting 3-hydroxybutyrate levels were over 80 μmol/l showed a consistent rise (mean, 145 μmol/l, n = 4) while the 2 individuals with lower levels (48 and 46 μmol/l) showed small falls. After guar, a more consistent fall was seen. The plasma NEFA values followed a similar pattern but were less consistent. Although the changes in plasma NEFA and blood 3-hydroxybutyrate concentrations did not correlate with the individual changes in peak blood glucose levels or glucose area of the subsequent GTT, they may well be markers of the metabolic effects of dietary fibre and indicate that events which are induced outside the GI tract by slow absorption of nutrients may be important in the way subsequent meals are handled.

Sipping glucose over 4 hours also flattened the rise in blood glucose seen after the subsequent glucose load. This situation, however, is probably not analogous to slow release of glucose from the guar gel as the glucose values were still elevated at 4 hours. In this case, the slow delivery of glucose may have 'primed' insulin secretory activity and resulted in the higher insulin levels seen.

In conclusion, a second important attribute should be added to the property certain types of dietary fibre have of flattening postprandial glycaemia; namely, the ability to improve the glucose tolerance of the subsequent meal. It is possible that a cumulative effect of this nature may help explain the gradual reduction and sometimes withdrawal, of insulin therapy found possible in diabetics on high-fibre diets [1].

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