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A Controlled Trial of a High Dietary Fibre Intake in Pregnancy – Effects on Plasma Glucose and Insulin Levels

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Summary. Non-obese women in the second half of pregnancy were randomised into a control group receiving standard dietary advice and a group advised to make high fibre wholefood substitutions in their diets at every opportunity. Glucose and insulin profiles were performed over 24-h periods at 29 and 35 weeks gestation when the diets were equivalent in available carbohydrate, protein and fat, but the control group ingested 12.4 g dietary fibre/24 h and the high fibre group 51.4 g/24 h. Glucose homeostasis was similar in both groups but there was a significant attenuation of post-prandial insulin secretion in the high fibre group. It is suggested that the characteristic post-prandial peaks of plasma insulin observed in Western pregnant women are an unphysiological response to dietary fibre depletion.

Key words: Dietary fibre, pregnancy metabolism, plasma glucose levels, plasma insulin levels.

European women on their normal diets show a deterioration in glucose homeostasis during pregnancy, on both oral and intravenous glucose tolerance testing [1, 2]. Cross-sectional studies on Kenyan and Nigerian African women showed improved glucose homeostasis in pregnancy relative to the non-pregnant state [3, 4]. It seems likely that this difference is of physiological significance and might relate to the low frequency of non-insulin dependent diabetes [5] and gestational diabetes [6] in Africans. African women obtain a greater proportion of their energy from carbohydrates and ingest more dietary fibre. This study was designed to isolate the effect of increasing dietary fibre intakes in pregnant European women without altering the available carbohydrate, protein, and fat ratios.

Subjects and Methods

A 'fibre substituted' diet has been devised from the tables of Southgate and Van Soest [7] and where suitable high and low fibre carbohydrate sources were available the former were recommended to the high fibre diet patients. By this means daily fibre intakes could be raised from an average of 10–15 g/24 h to 50–60 g/24 h.

Healthy primigravid patients whose non-pregnant weights were < 110% of ideal for height [8] and who had no family history of diabetes were recruited and randomised into two groups. The randomisation was performed by opening sealed envelopes after the patients had agreed to participate. The control group ($n = 12$) were interviewed at 27 weeks gestation by a dietitian who gave them standard advice on diet in pregnancy, suggesting a calorie intake of approximately 2,400 [9]. The high fibre diet group ($n = 13$) had a similar interview but were advised to reduce their intakes of sucrose and white flour, and to make as many high fibre substitutions as possible, whilst aiming for a similar energy intake. They were given diet and recipe sheets and tokens for free wholemeal bread to encourage compliance. All patients were seen by the dietitian at their antenatal attendances. The study was approved by the Ethical Committee of the North Sheffield District Health Authority.

Antenatal care accorded with the hospital routine and in addition serial measurements of human placental lactogen and ultrasound measurements of biparietal diameter were performed. All patients were provided with routine oral iron supplements and serial measurements of haemoglobin and serum ferritin were performed.

Both groups were admitted at 29 and 35 weeks gestation and blood samples were withdrawn through indwelling cannulae over 24 h periods during which they were given standardised diets (Table 1). Breakfast was eaten between 0800 and 0830 h at home before admission. The control diet was an unexceptional hospital menu and the study diet had high fibre substitutions where possible. The diets were standardised with respect to available carbohydrate, protein and fat as percentages of total calorie intake. The carbohydrate and fibre intakes at each meal are summarised in Table 2. After overnight fasting each patient was given a 75 g oral glucose load in 200 ml water. Heparinised blood samples were stored at 4 °C before plasma separation. Plasma was stored at − 20 °C before assay of glucose by a glucose oxidase method [10] and insulin by radioimmunoassay [11]. Maternal weight gain during the study period was monitored. Newborn weight for gestational age [12], length, head circumference and subcutaneous fat thickness were measured. Plasma insulin and glucose levels were compared between groups at each time point. Mean diurnal values between 1000 and 0600 h and mean post load values between 0700 and 1000 h were also compared.

Statistical analyses were by the Mann-Whitney two tail probability test.

Table 1. Menu of food taken during the 24-h profiles on control and high fibre diets

	Control diet	High fibre diet
Breakfast	Boiled egg, Rice Crispies, white bread, sugar, tea or coffee	Baked beans, wholemeal bread, Weetabix, tea or coffee
Mid-morning snack	Rich tea biscuits, sugar, tea or coffee	Digestive biscuits, tea or coffee
Mid-day meal	Chicken, cabbage, boiled potatoes, tinned fruit, ice cream, sugar, tea or coffee	Chicken, peas, chipped potatoes, unsweetened fruit, tea or coffee
Mid-afternoon snack	Rich tea biscuits, sugar, tea or coffee	Banana nut loaf, tea or coffee
Evening meal	Beef, carrots, boiled potatoes, jelly, cream, sugar, tea or coffee	Beef, salad, wholemeal bread, apple tart, tea or coffee
Supper	Cream crackers, cheese, tea or coffee	Banana, wholemeal bread, tea or coffee
Taken with meals	Milk, butter	Milk, butter

Total		Percentage of calories (%)		Percentage of calories (%)
Calories	2403		2355	
Carbohydrate (g)	260	43	258	44
Protein (g)	111	18.5	104	17.5
Fat (g)	103	38.5	101	38.5
Dietary fibre (g)	12.4		51.4	

Results

Figure 1 shows the glucose and insulin profiles in control and high fibre diet patients at 29 weeks gestation and Figure 2 the results at 35 weeks gestation. Mean ± SEM diurnal plasma glucose levels were significantly lower in the control group than in the high fibre diet group at 29 weeks but not at 35 weeks (controls 29 weeks: 4.80 ± 0.07 mmol/l, high fibre 29 weeks: 5.09 ± 0.07 mmol/l, $p < 0.001$; controls 35 weeks: 4.90 ± 0.08 mmol/l, high fibre 35 weeks: 4.77 ± 0.07 mmol/l).

There was no significant difference in the control group's diurnal glucose levels between 29 and 35 weeks. Both groups showed a significant elevation of mean diurnal insulin levels at 35 weeks compared to 29 weeks (controls 29 weeks: 58.9 ± 4.5 mU/l, 35 weeks: 93.1 ± 5.8 mU/l, $p < 0.0001$; high fibre 29 weeks: 46.7 ± 3.3 mU/l, 35 weeks: 63.8 ± 3.8 mU/l, $p < 0.0001$). There was a trend to higher post-prandial peaks of plasma insulin in the control patients after each meal which was significant after the evening meal at 29 weeks and after the morning snack and mid-day meal at 35 weeks. Mean diurnal insulin levels were significantly higher in the control group relative to the high fibre diet group at 35 weeks ($p < 0.0001$). After glucose loading there was a non-significant trend to lower plasma glucose levels in the high fibre group at 29 and 35 weeks. This trend was accompanied by significantly lower plasma insulin levels at both stages of gestation.

Results of the antenatal monitoring (including maternal weight gain and serum ferritin) and fetal anthropometry showed no significant differences between the groups.

Discussion

There is evidence that diabetic control in both insulin and non-insulin dependent patients is improved by a high fibre diet [13–16]. The importance of qualitative as well as quantitative assessment of carbohydrate sources in the diabetic diet has been confirmed by the demonstration of reduced glycaemia in non-diabetics after high fibre test meals [5, 17].

Jenkins showed that such improvements in glycaemic control were accompanied by reduced insulin secretion [18]. The effect was demonstrated in this study by the response to 75-g glucose loading. Whether the reduction in insulin secretion represented an improved peripheral sensitivity to insulin, or was a reaction to a simultaneous reduction in the release of gastric inhibitory polypeptide or enteroglucagon remains unresolved, although experiments in which guar was added to glucose loads suggest that the second alternative is less likely [19].

The current study was performed in late pregnancy when insulin secretion is greater than in the non-pregnant state, but there is no reason to assume that similar attenuations of post-prandial peak levels of insulin do

Table 2. Total available carbohydrate and total dietary fibre at each meal in control and high fibre diets

	0800 h Breakfast	1030 h Mid-morning	1200 h Mid-day	1515 h Mid-afternoon	1730 h Evening meal	2130 h Supper	Total
Control diet							
Carbohydrate (g)	50	21	64	21	59	20	260[a]
Dietary fibre (g)	2.2	0.3	5.0	0.3	4.2	0.4	12.4
Fibre-substituted (study) diet							
Carbohydrate (g)	51	20	63	22	59	18	258[a]
Dietary fibre (g)	18.3	1.6	13.6	3.0	11.5	3.4	51.4

[a] The total includes 560 ml of milk consumed ad libitum during the day

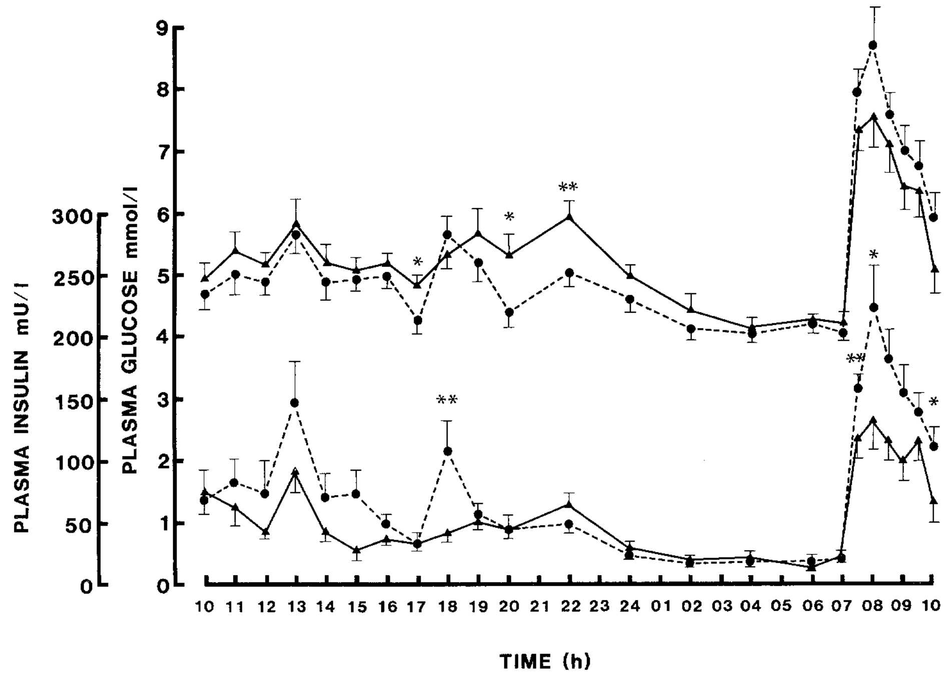

Fig. 1. Twenty-four hour plasma glucose (upper section) and plasma insulin levels (lower section) observed at 29 weeks gestation (mean ± SEM) in the control group (●---●) and high fibre diet group (▲—▲). The significance of differences at each time point are shown as $*p<0.05$, $**p<0.01$

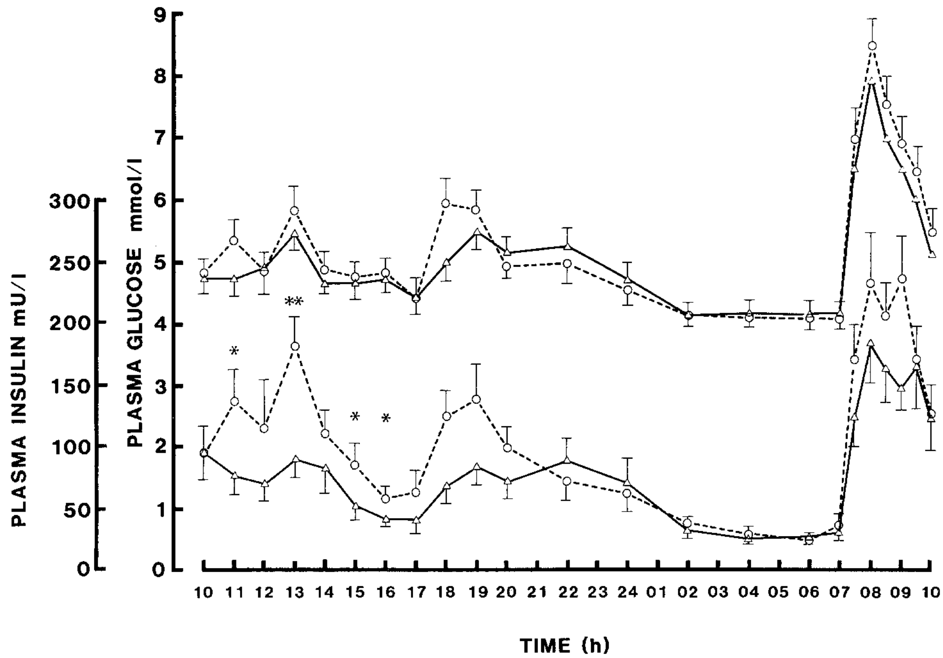

Fig. 2. Twenty-four hour plasma glucose (upper section) and plasma insulin levels (lower section) observed at 35 weeks gestation (mean ± SEM) in the control group (○---○) and high fibre diet group (△—△). The significance of differences at each time point are shown as $*p<0.05$, $**p<0.01$

not occur in non-pregnant subjects on high fibre diets, although absolute values may be lower.

Frienkel and Metzger [20] have argued that the fault in mild gestational diabetes is a deficiency of the acute insulin response to mixed meal feeding, accompanied by a delayed insulin response which exceeds control values. A high fibre diet, which moderates the stimulus to acute post-prandial peak secretion of insulin, might be expected to correct this fault and reduce glycaemia.

Diets high in cereal fibre have a high phytate content and tend to bind divalent cations in the gut [21]. It was reassuring that the mean serum ferritin levels remained in the normal range in the high fibre diet group with no significant fall between 29 and 35 weeks. Normoglycaemia was maintained in the high fibre diet group despite their reduced insulin secretion and there was no discernable difference in fetal growth or neonatal anthropometry compared to the control patients and their babies.

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