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Effects of Dietary Fibre Supplementation in Stable and Labile Insulin-dependent Diabetics

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Summary. Seven stable and 10 labile insulin-dependent diabetic patients were submitted to 2 dietary regimens which were given in random order and maintained for 10 to 15 days. During one period ("control") patients were given their usual diets. During the other period patients received a fibre supplemented diet ("test"). The fibre supplementation was calculated to provide 1 g dietary fibre per 15 g available carbohydrate. For each period, diabetic control was estimated from: (i) daily glycosuria; (ii) % glycosylated haemoglobin, (iii) insulin requirements, (iv) frequency of hypoglycaemic episodes and (v) circadian blood glucose levels. Dietary fibre supplementation resulted in: (i) decreased glycosuria in both stable (12.8 ± 5.6 g/day vs 25.5 ± 6.9 $P < 0.01$) and labile diabetics (35.8 ± 10.5 g/day vs, 52.5 ± 7.1, $P < 0.02$); (ii) a significant decrease in blood glucose at 1430h ($P < 0.02$) in stable and at 1430 h ($P < 0.05$) and 2030h ($P < 0.01$) in labile diabetics. The percentage of glycosylated haemoglobin was identical in stable (10.8 ± 1.0%) and labile diabetics (10.7 ± 1.0) and was slightly depressed with the fibre supplemented diet (9.5 ± 0.8 and 9.3 ± 0.6 respectively). The mean blood glucose during the control period was not significantly different in stable (186 ± 28 mg/100 ml) and labile diabetes (221 ± 24 mg/100 ml) and did not change significantly with fibre treatment. The results show that the control of stable and labile diabetes is improved to a similar degree by dietary fibre. This effect results mainly from a decrease in post prandial hyperglycaemia after lunch and dinner.

Key words: Dietary fibre, stable diabetes, labile diabetes, glycosylated haemoglobin, glycaemic control.

Epidemiological surveys have suggested that high fibre diets reduce the frequency of diabetes mellitus [1, 2] and there is some evidence that the supplementation of normal meals with certain types of dietary fibre such as pectins, guar and hemicelluloses results in a decrease of post-prandial hyperglycaemia [3, 4, 5, 6]. The course of insulin-dependent diabetes is characterized by rapid fluctuations in blood glucose [7] and frequently by adverse responses to insulin therapy (such as hypoglycaemic episodes). In order to obtain optimum diabetic control, the dosage of subcutaneous insulin must be carefully adjusted each day and long term dietary measures observed. The need both to reduce the percentage of available carbohydrates in the diet of diabetic patients and to avoid nutrients containing concentrated refined carbohydrates has been long recognized, but despite these measures many patients continue to show poor glycaemic control. Dietary fibre has been reported to benefit control in "chemical diabetes" [8], non-insulin dependent diabetes [3] and insulin-dependent diabetes [9, 10, 11, 12]. Here we report a study comparing the effects of high fibre diets on diabetic control in patients with stable or labile insulin-dependent diabetes.

Materials and Methods

Subjects

Seventeen insulin-requiring diabetic patients, 22–71 years (mean, 48 years) were studied after their informed consent had been obtained. The mean % ideal body weight of the patients ± SD was: 102 ± 9% (range: 84–120%) at the start and 103 ± 9% (84–118%) at the end of the study. Mean ideal body weight was estimated from the tables of the Metropolitan Life Insurance Co. The patients were separated into labile and stable diabetics by calculating the mean amplitude of glycaemic excursions (Mage) [7, 13, 14].

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Table 1. Patient data. Group I corresponds to stable diabetics (Mage< 126 mg/100 ml) and Group II to labile diabetics (Mage > 126 mg/100 ml)

Patients	Sex	Age (years)	% ideal body weight at the start	at the end	Duration of diabetes (years)	Mage values (mg/100 ml)	Diet: Available carbohydrates (g/day)	Diet: Dietary fibres during control and test periods (g/day)		Insulin injection before the study: Daily dose units	Type	Daily frequency
Stable diabetics												
1	M	50	108	108	7	100	250	18	35	28	NPH	2
2	M	44	83	83	31	90	250	18	35	40	Reg+UL	1
3	M	55	103	106	10	125	170	16	27	42	SL+L	1
4	M	43	90	93	12	110	220	22	37	55	SL	2
5	M	48	107	108	13	60	250	18	35	73	NPH	2
6	F	65	108	108	10	115	200	16	30	44	L	1
7	M	70	93	93	16	105	200	16	30	61	SL	2
Mean		54	99	103	14	100	220	18	33			
±SD		10	10	4	8	21	31	2	4			
Labile diabetics												
8	M	71	105	105	32	180	150	15	25	50	Reg	3
9	M	46	90	92	31	210	215	20	35	32	SL+L	1
10	M	55	92	98	25	195	250	18	35	28	SL	2
11	M	46	105	106	16	300	250	18	35	36	SL	2
12	F	43	100	105	10	150	200	16	30	76	Reg+L	1
13	M	47	108	109	12	270	180	18	30	50	SL	2
14	M	31	120	118	8	155	200	17	30	39	SL	2
15	F	22	101	100	11	230	110	16	23	51	Reg	3
16	M	59	108	108	28	130	220	22	37	46	SL+L	1
17	M	26	108	108	15	340	230	20	36	79	Reg+L	1
Mean		45	105	105	19	216	200	18	31			
± SD		15	8	7	9	68	44	2	5			
Group I + Group II												
Mean		48	102	103	17		208	18	32.0			
± SD		14	9	8	9		39	2	4.3			

Reg: Regular insulin
SL: Semi Lente
L: Lente
UL: Ultra-lente
Mage: mean amplitude of glycaemic excursions (see [13])

Table 2. Comparison of the criteria of diabetic control. Control and test periods correspond respectively to periods with and without dietary fiber supplementation. Mean blood glucose is the average of circadian variations obtained from blood samples at 0000,0400, 0800, 0930 1200, 1400, 1830 and 2030 h. Glycosuria corresponds to the average total daily excretion of glucose for each period

Type of diabetes		Stable		Labile		Labile + Stable	
Period of investigation		Control	Test	Control	Test	Control	Test
No. of patients		7	7	10	10	17	17
Mean blood glucose concentration (mg/100 ml)	Mean	186	171	221	192	206	184
	SEM	28	22	24	24	18	17
Glycosuria (g per day)	Mean	25.5	12.8[c]	52.5	35.8[b]	40.4	26.0[c]
	SEM	6.9	5.6	7.1	10.5	6.2	7.1
Glycosylated haemoglobin (%)	Mean	10.8	9.5[a]	10.7	9.3[a]	10.8	9.4[a]
	SEM	1.0	0.8	1.0	0.6	0.7	0.5
Insulin requirements (units per day)	Mean	51	52	49	50	50	51
	SEM	6	7	6	6	4	5
No. of hypoglycaemic episodes per week	Mean	1.6	2.5	2.7	3.3	2.2	3.0
	SEM	0.6	1.0	0.8	0.6	0.5	0.5

[a] $P < 0.1$, [b] $P < 0.02$, [c] $P < 0.01$ compared with appropriate control

All results are given as mean ± SEM. Statistical differences, established by Wilcoxon signed ranktest, are only indicated when significant

Seven patients with Mage values lower than 126 mg/100 ml (Group I) were considered stable. The 10 other patients (Group II) had Mage values greater than 126 mg/100 ml and were considered to be labile. In order to avoid any interference from treatment the patients selected for the study received no medication other than their insulin. Additional clinical details are given in Table 1.

Protocol

Each patient was submitted to a dietary trial divided into 2 successive periods ranging from 10 to 15 days. All patients were hospitalized for the entire study Throughout the investigation (i. e during the two periods) the content of the diet in available carbohydrate was supervised by the dietitians and maintained at a value which was constant and similar to the normal intake of the patient. Available carbohydrates provided 40 per cent of total calories (range: 110 to 250 g per day), while lipids and proteins accounted respectively for 45 and 15 per cent. Meal times were standardized and comprised 3 main meals (breakfast, lunch and dinner) and 3 snacks (mid-morning, mid-afternoon and bed time).

Control Period. The patients were submitted to a low fibre intake [15] ranging from 15 to 23 g and corresponding to their usual intake (Table 1). The dietary fibre intake was estimated from food composition tables [16].

Test Period. The patients received the same diet as above supplemented with a dietetic preparation derived from wheat bran. The test bread was given in 2.3 g units (Cerefibres Gressins, supplied by Meram Lab. France) each of them providing 8 Calories, 1 g of available carbohydrate and 1 g of dietary fibre. The number of units given to each patient was calculated to provide an additional intake of 1 g of dietary fibre for 15 g of available carbohydrate contained in the food. Alternatively, the available carbohydrates provided by the test bread were substracted from the regular diet in order that the intake of available carbohydrates during the two periods was similar. Thus a patient fed 150 g of available carbohydrates during the control period was supplemented with 10 g of dietary fibre, i. e 10 units of test bread, during the test period. During the latter period the patient received respectively 140 g of available carbohydrate from his regular diet and 10 g from the test bread. The intakes of available carbohydrates and dietary fibres are detailed for all patients in Table 1 for each dietary sequence. The order of taking control and test diets was randomized.

Diabetic Control for each patient was estimated in the following ways. (i) Glycosuria was determined every day by Clinitest tablets (Ames Co) on total 24 h urine collections, using the usual scale: 0, 1/4, 1/2, 3/4, 1 and 2% (g/100 ml). When glucose concentrations were higher than 2 g/100 ml, calculations were made on results obtained from diluted urinary samples. The total glucose excreted every day was then averaged for each period. (ii) The percentage of total glycosylated haemoglobin (Hb A_1) was measured at the end of each period by chromatographic separation using the Isolab system based on the methodology of Schnek et al. [17] (coefficient of variation: 2%); (iii) The patient's insulin requirements were recorded. (iv) The frequency of hypoglycaemic episodes was expressed as number per week. (v) The circadian pattern of blood glucose (Neocuproine Auto Analyzer) by regular timed blood sampling during fasting (at 0000, 0400, 0800, 1200 and 1830 h) and post prandial periods (at 0930, 1400 and 2030 h) was measured over the last day of each dietary sequence.

Statistical Analysis. All results are given as mean ± SEM. Data were compared by the Wilcoxon signed ranking test which does not require normal distribution and large sample sizes.

Results

Glycosuria was markedly and significantly lower with fibre supplementation for both groups (Table 2).

Glycosylated haemoglobin was similar in labile (10.7 ± 1%) and stable diabetics (10.8 ± 1%) when receiving their usual diet. As shown in Table 2 a slight drop at the 10% level of statistical significance ($P < 0.1$) was observed in both groups of patients after dietary fibre supplementation.

Insulin requirements in both groups I and II remained unchanged whether patients were under dietary fiber supplementation or not (Table 2).

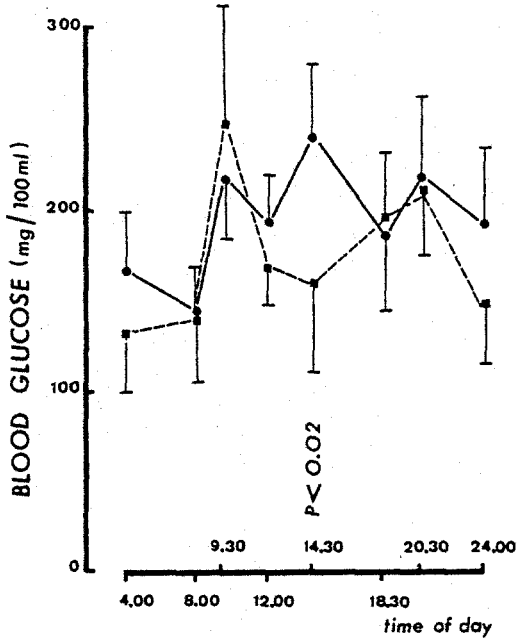

Fig. 1. Diurnal patterns of blood glucose concentrations in 7 stable diabetic patients with (■) and without (●) fibre supplementation. Meals were given at 0800, 1200 and 1900h. Snacks were given at 1000, 1600 and 2200 h. The Wilcoxon signed ranking test is used for statistical comparisons

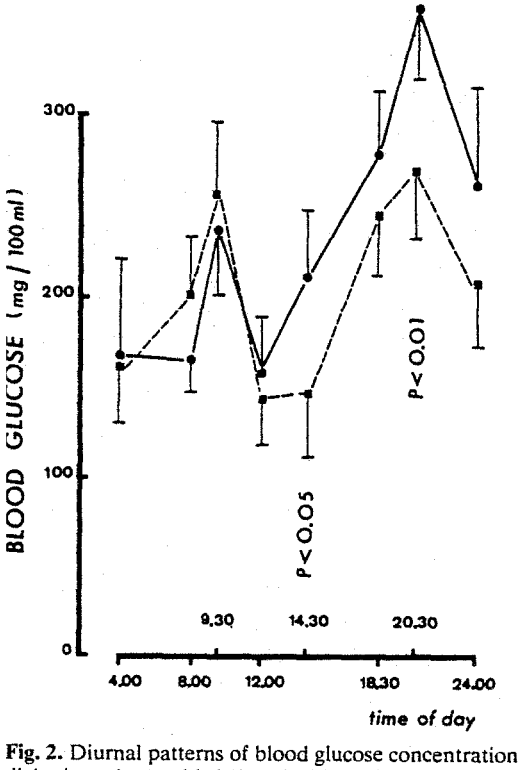

Fig. 2. Diurnal patterns of blood glucose concentration in 10 labile diabetic patients with (■) and without (●) fibre supplementation. Meals were given at 0800, 1200 and 1900 h. Snacks were given at 1000, 1600 and 2200 h. The Wilcoxon signed ranking test is used for statistical comparisons

The number of hypoglycaemic episodes per week was identical during the two periods, whether patients had stable or labile diabetes.

The circadian patterns of blood glucose concentrations are shown on Figure 1 and 2 for patients with stable and labile diabetes respectively. The statistical analysis indicates that fasting blood glucose concentrations were similar whether patients were supplemented or not with dietary fibre. In stable diabetics post-prandial glucose levels at 1430 h were significantly lower during the high fibre period compared to the control period (Fig. 1). In labile diabetics a significant diminution in post-prandial glucose levels was noted at 1430 and 2030 h during fibre supplementation (Fig. 2). In both groups similar blood glucose values were observed after breakfast.

The mean blood glucose, i. e the average of glycaemic circadian variations was identical in both groups and during both periods.

Discussion

From the present study, it appears that post-prandial rises in blood glucose are significantly blunted by dietary fibre supplementation after lunch and dinner in labile diabetics, and after lunch in stable diabetics. This slight improvement in post-prandial hyperglycaemia is accompanied in both types of diabetes by a significant and similar fall in daily glycosuria, while insulin requirements remained unchanged. The slight decrease in percent glycosylated haemoglobins observed in both groups of patients tends to confirm that the carbohydrate homeostasis of insulin-requiring diabetics is improved by high fibre diets. Similar results have been previously observed by other authors in insulin-requiring diabetics [9, 10, 11, 18], but the present data indicate that labile and stable diabetics are improved to a similar, although small, degree by dietary fibre supplemented diets.

The beneficial effect of fibre is usually attributed either to slower gastric emptying or to formation of unabsorbable complexes with available carbohydrates in the gut lumen [3, 4, 12]. Therefore it has been suggested that these two properties might result both in delayed absorption of carbohydrates, and in reduction of the absolute quantity absorbed. The present study seems to indicate that absorption of calories and sugar into the blood stream was not reduced by dietary fibers since the patients did not exhibit any change in mean insulin-requirement, frequency of hypoglycaemia or body weight whether they were supplemented or not. However in other studies, it has been observed that fibre supplementation resulted in a significant fall of patient's insulin

requirements [9, 18, 19]. When insulin doses were kept constant and similar under low and high fibre diets, as in Miranda's study [11], the number of hypoglycaemic episodes was significantly increased during the high fibre period. The discrepancies between these results and ours might be due to the fact that we added less fibre to our diets (23 to 37 g of dietary fibre daily i. e 8 to 16 g of crude fibre) than Miranda (20 g crude fibre daily) [11], and Jenkins (25 g guar gum daily) [9]. It seems therefore possible that the very high fibre diets used by these authors might not only have delayed but also reduced the absorption of carbohydrates.

Recent studies suggest that the quality of fibre may be as important as the quantity. Thus high viscosity preparations such as pectin and guar seem to have a considerable post prandial hypoglycaemic effect [4, 8, 20] in contrast to cellulose and its low-viscosity derivatives which do not [20]. The fibre supplementation used in the present study was a wheat bran preparation. Hemicelluloses, which are the most abundant fibre components of bran are in many ways similar to guar and pectin. Our study shows that bran is effective, at least in the short term, and has the advantage over pectin and guar of greater patient acceptibility.

Fibre supplementation lowered the glycosylated haemoglobulin levels to the same extent in stable and labile diabetics. Furthermore, during the control (low fibre) period, the mean blood glucose was identical in stable and labile diabetes. Thus it appears that the wide and frequent glycaemic excursions found in labile diabetics are associated with mean blood glucose concentrations and glycosylation rates similar to those observed in stable diabetics with mild sustained hyperglycaemia. These findings are in agreement with the concept that glycosylation of haemoglobins depends both on the duration and degree of blood glucose elevation [21–24]. Therefore, although glycosylated haemoglobin levels are a useful indicator of hyperglycaemia over prolonged periods, they obviously do not help in assessing the stability or lability of diabetes mellitus [25].

HbA_1 concentrations fell after only a short period of fibre supplementation. The glycosylation of haemoglobin is, however, considered to be a slow and non reversible process, characterised by a progressive accumulation of HbA_1 through the 120 day-life span of the circulating red cells. Thus concentrations of HbA_1 usually decrease only after a delay of 1 or 2 months following improved blood glucose control. For that reason, the decrease in HbA_1 seen under fibre supplementation in the present study must reflect either a rapid fall in HbA_1 production, i. e a dramatic improvement in diabetic control, or a reversibility of the glycosylation process. Our data seems support the latter hypothesis and we suggest with others [26, 27] that haemoglobin glycosylation is in part reversible.

Several conclusions can be drawn from the present study. First, our results confirm that dietary fibre supplementation improves to some extent diabetic control of insulin-dependent diabetics. Second, beneficial effects are obtained with the addition of moderate amounts of fibre. The use of moderate supplementation rather than high fibre diets, which might result in long term adverse side effects, may therefore be recommended although changes were small. Third, stable and labile diabetes are improved to a similar degree be dietary fibre.

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