6 patients. More recent studies have supported the concept that high carbohydrate diets may have a beneficial impact on the control of diabetes (Kempner *et al.*, 1958); Patel *et al.*, 1969; Brunzell *et al.*, 1971, 1974; Gulati *et al.*, 1974; Viswanathan, 1978; Anderson and Ward, 1978, 1979).

High carbohydrate, high fibre diets

Diets providing large amounts of unrefined carbohydrate and dietary fibre are beneficial in the management of many persons with diabetes (Singh, 1955; Gulati *et al.*, 1974; Viswanathan, 1978). We have systematically studied the effects of weight-maintaining, high carbohydrate, high fibre (HCF) diets in lean individuals with diabetes (Kiehm *et al.*, 1976; Anderson and Ward, 1978, 1979). The composition of representative diets is given in Table 22.1. We have usually fed control diets for 7–11 days and then fed HCF diets for 12–28 days. Patients have then been instructed in maintenance diets for home use. The carbohydrate, protein and fat contents of the control diets are similar to conventional diabetic diets; however, the control diets have less cholesterol and more dietary fibre than most conventional diets. The HCF diets provide 70 per cent of energy from carbohydrate and have large quantities of dietary fibres. The maintenance diets resemble the diets recommended (West, 1975) as prudent diets for persons with diabetes. Our experience with these HCF diets will be briefly summarized.

The response of a representative patient is presented in Fig. 22.4. On the control diet, this man required 32 units of insulin daily to maintain fasting plasma glucose values of approximately 9·2 mmol/l (165 mg/dl) and urine glucose excretion of 33 mmol/d (6 g/d). On the HCF diet his plasma glucose and urine glucose values declined and insulin could be reduced rapidly. After 16 days on the HCF diet his insulin could be discontinued. After insulin was discontinued, his fasting plasma glucose values remained under 10 mmol/l (180 mg/dl) and his urine glucose excretion below 35 mmol/d (6·3 g/d). On the maintenance diet at home he has had fasting glucose values ranging from 7·8 to 10 mmol/l (140–180 mg/dl) for nine months without insulin or sulphonylurea therapy.

Whereas weight-maintaining conventional diets or other isocaloric diets do not greatly alter glucose metabolism or insulin requirements (Kuhl, 1956; Hallgren and Svanborg, 1962), these HCF diets are accompanied by prompt reductions in insulin doses. Twelve lean men were treated with control diets for 7–11 days; there were no significant changes in insulin doses (Fig. 22.5). They then received weight-maintaining HCF diets and insulin doses could be lowered quickly. However, fasting plasma glucose and urine glucose values were significantly lower on HCF diets than values on control diets. Our experience with 33 insulin-treated patients is summarized in Fig. 22.6. Seventeen patients ((11 lean, 6 obese) were treated with 14–20 units of insulin per day on control diets. On HCF diets insulin could be discontinued in 16 of 17 patients after an average of 14 days. Eleven lean men required 25–32 units of insulin per day on control diets. On weight-maintaining HCF diets,

Table 22.1 Composition of representative 1800 kilocalorie diets[1]

	Control diet		HCF diet		Maintenance diet	
	g/d	% kcal	g/d	% kcal	g/d	% kcal
Protein	92	20	98	21	90	20
Carbohydrate, total	193	43	314	70	261	58
Simple	79	—	91	—	65	—
Complex	114	—	223	—	196	—
Fat, total	74	37	18	9	44	22
SAT[2]	26	—	5	—	12	—
MUS[2]	39	—	5	—	18	—
PUS[2]	9	—	7	—	12	—
Cholesterol	0·48	—	0·065	—	0·10	—
Dietary fibre	26	—	65	—	51	—

[1] From Anderson and Ward (1978, 1979)
[2] SAT, saturated; MUS, monounsaturated; and PUS, polyunsaturated fatty acids

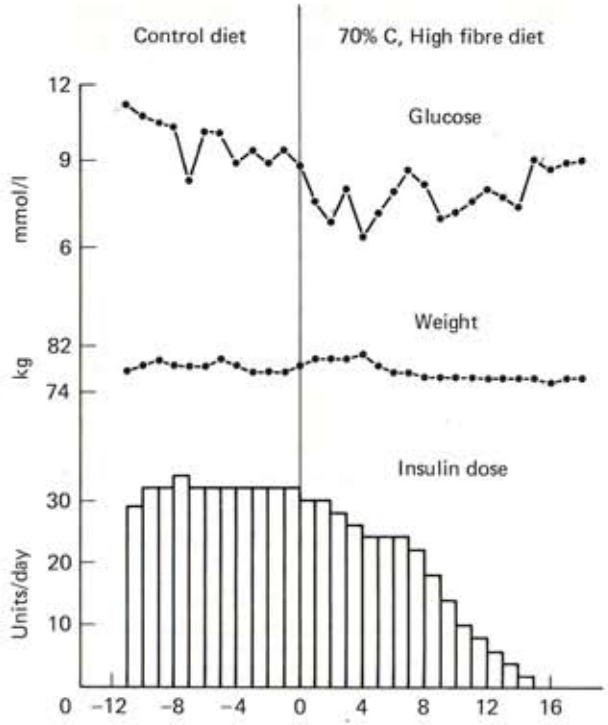

Fig. 22.4 Response of diabetic man to control and high carbohydrate, high fibre diets. Fasting plasma glucose values are presented in top line (Anderson and Ward, 1979)

insulin was reduced by an average of 1 unit per day and could be discontinued in five of these patients. For example, one man had been treated with 35–40 units of insulin per day for the previous six years. He required 32 units of insulin to maintain fasting plasma glucose values of approximately 8·3 mmol/l (150 mg/dl) and urine glucose values of 17–33 mmol/d (3–6 g/d). On the HCF diet, insulin was reduced by 2 units on alternate days and was discontinued after 33 days. Without insulin on the HCF diet his fasting plasma glucose values averaged 8·9 mmol/l (160 mg/dl) and his urine glucose excretion was less than 28 mmol/d (5 g/d). These studies suggest that HCF diets may have distinct therapeutic advantages for many patients with the maturity-onset (insulin-independent) type of diabetes.

Five lean adults with the juvenile-onset (insulin-dependent) type of diabetes have been treated with weight-maintaining HCF diets. These patients required an average of 44 units per day (range 40–55 units/d) on control diets. On HCF diets, plasma glucose and urine glucose values were slightly lower than values on the control diets and insulin doses were reduced to 34 units per day (range 20–46 units/d). The management of three patients was

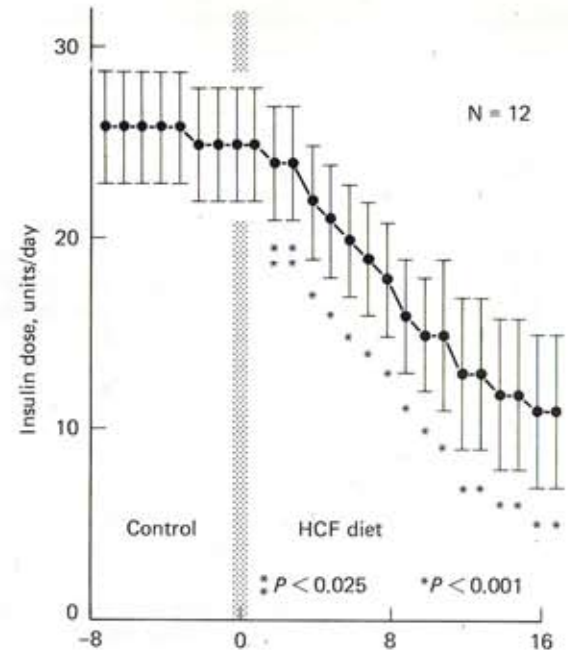

Fig. 22.5 Insulin requirements of lean diabetic men on control and HCF diets. These studies of Anderson *et al.* (1978) are described in text

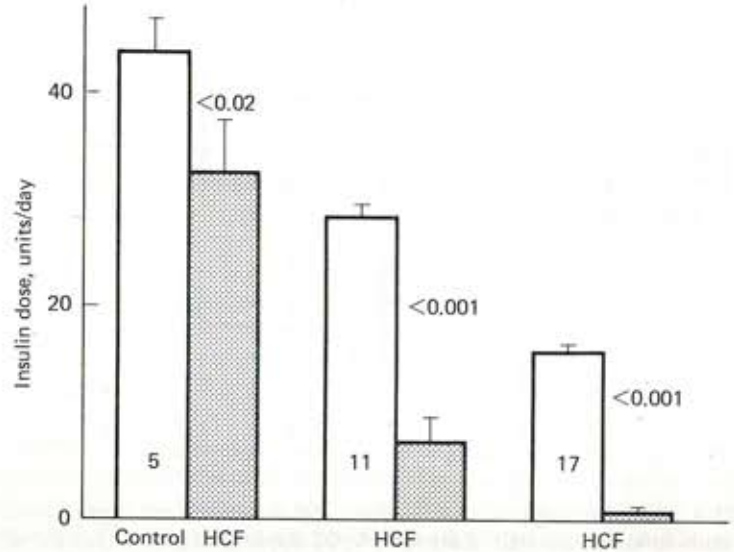

Fig. 22.6 Insulin doses of diabetic patients on control and HCF diets. These studies of Anderson *et al.* (1978) are described in text

distinctly improved by HCF diets: insulin reactions were less common and fluctuations in plasma glucose concentration were less marked than on the control diets. We have not treated any children with HCF diets and from our limited experience we are not able to assess the value of these diets for patients with the juvenile-onset type of diabetes.

After discharge from the hospital, patients who have responded well to HCF diets have sustained these improvements on maintenance diets providing approximately 60 per cent of energy as carbohydrate and 50 g of dietary fibre per day (Table 22.1). We have followed 15 patients for 6–48 months on these maintenance diets (Fig. 22.7). On HCF diets in the hospital, insulin was discontinued in 11 patients; one additional patient discontinued insulin after discharge from the hospital. Over an average period of 16 months on the maintenance diets, insulin doses have remained stable in 3 patients and the remaining 12 have been maintained without insulin. Fasting plasma glucose values in these patients have averaged approximately 8 mmol/l (144 mg/dl) (Fig 22.8). In sharp contrast, 9 patients who responded well to HCF diets in the hospital elected to resume their conventional (termed ADA) diets as out-patients. Within one to three weeks after discharge, their insulin doses returned to values which are similar to values on the control diet in the hospital (Fig. 22.7). These studies suggest that diets providing approximately 60 per cent of energy from carbohydrate and containing generous quantities of dietary fibre are useful in the long-term management of diabetes. These

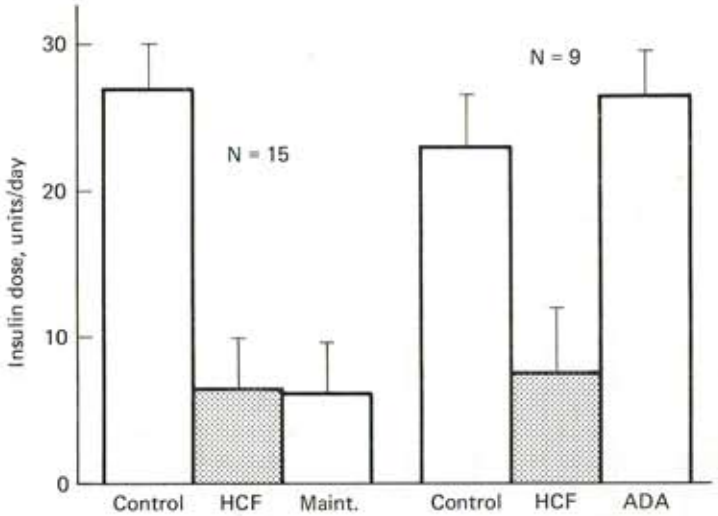

Fig. 22.7 Insulin doses on various diets. Patients were on control diets for 5–11 days followed by HCF diets for 14–33 days. One group (left panel) were discharged from the hospital on high fibre maintenance diets while the other group (right panel) resumed conventional (ADA) diets as out-patients. These studies of Anderson *et al.* are described in text

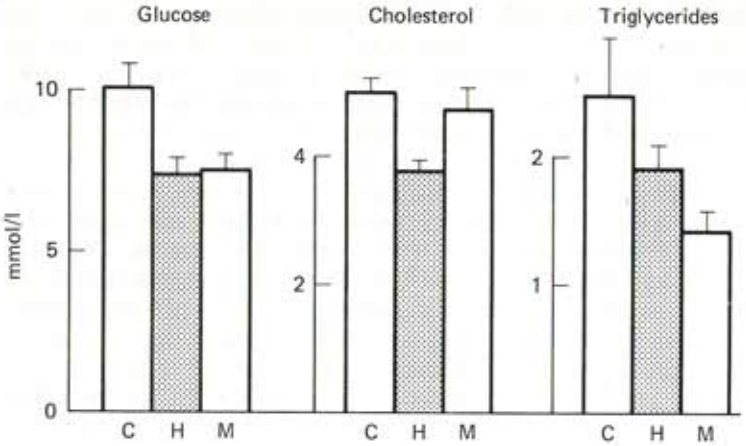

Fig. 22.8 Responses to control (C), HCF (H) and maintenance (M) diets of diabetic patients. Fasting plasma glucose and serum lipids were measured by Anderson *et al.* as described in text

diets have been well tolerated and not associated with appreciable gastro-intestinal side effects. We have made serial measurements of haemoglobin, serum calcium, phosphorus, alkaline phosphatase, iron, magnesium, carotene, folate, prothrombin and partial thromboplastin times on these patients and have not detected alterations on these maintenance diets.

At the present time we do not understand the mechanisms responsible for the improved glucose metabolism and reduced insulin doses on HCF as compared to control diets. Other studies (Anderson, 1979) suggest that changes in the carbohydrate and fat content of these diets might play a major role and that dietary fibre might have a minor role in the improved glucose metabolism. The intake of most of the carbohydrate in the unrefined form (i.e. in its natural fibre packages), probably does reduce post-prandial plasma glucose concentrations. These diets appear to increase tissue sensitivity to insulin since insulin doses were reduced in patients with the insulin-dependent type of diabetes. Our studies of insulin binding to circulating monocytes demonstrated that monocytes bound more insulin and have significantly greater numbers of insulin binding sites ($P < 0{\cdot}001$) when patients were on HCF diets than observed on control diets (Anderson, 1979). Many patients respond rapidly to HCF diets (Fig. 22.5) and then have a slow adaptive response similar to that reported by Jenkins and colleagues (Jenkins *et al.*, 1978b, 1979). Two lean patients who were on 32 units of insulin on control diets illustrate this slow response. The first patient, as outlined above, required 33 days of treatment with the HCF diet before insulin could be discontinued. The second patient had received 30–40 units of insulin per day for 19 years and was reasonably well controlled on 32 units on the control diet. During a 21-day period on the HCF diet, his insulin gradually was reduced to 8 units per day. On the maintenance diet at home, he was able to

reduce slowly the insulin dose and discontinue insulin ten weeks after discharge. He now has gone 18 months without insulin and has had fasting plasma glucose values ranging from 7·2 to 10 mmol/l (130–180 mg/dl) without insulin therapy. Obviously those patients who are able to discontinue insulin have residual endogenous insulin secretion which is able to maintain their glucose homoeostasis after discontinuing exogenous insulin.

Serum lipid responses have been evaluated in over 60 patients treated with HCF diets on our metabolic ward. Every patient has had a reduction in serum cholesterol values (Fig. 22.8). The average reduction in serum triglycerides has been 16 per cent ($P < 0{\cdot}01$). Patients with normal serum triglyceride concentration show little change in values on HCF diets. However, patients with hypertriglyceridaemia almost invariably have a distinct reduction in fasting serum triglyceride values while on the HCF diets. Twelve patients with hypertriglyceridaemia on control diets had fasting values ranging from 3·5 to 33·6 mmol/l (312–2970 mg/dl, average 1147); after 12 days on weight-maintaining HCF diets, serum triglyceride values were lower in every patient and average values were 63 per cent lower ($P < 0{\cdot}01$). The dietary fibre content of these diets seems to be responsible for this triglyceride lowering effect since patients fed low fibre, high carbohydrate diets develop hypertriglyceridaemia with regularity (Anderson, 1977a). After discharge from the hospital, serum triglyceride values usually are even lower on the maintenance diets (Fig. 22.8). Thus, high fibre diets may have a substantial role in the management of hypertriglyceridaemia. Our experience indicates that HCF diets lower average cholesterol and triglyceride values in patients with diabetes and that these reductions are sustained on the home maintenance diets. These improvements in lipid metabolism may lessen the risk for arteriosclerotic vascular disease in these patients with diabetes.

Conclusion

In most Western countries, traditional diabetic diets have been restricted in carbohydrate and dietary fibre. These diets have provided more animal fat and cholesterol than the usual diets of non-diabetic individuals in these countries. The large intake of animal fat and cholesterol may have contributed to the high prevalence of arteriosclerotic vascular disease among persons with diabetes in Western countries. Carbohydrate intake has been restricted for empirical reasons and there are no careful metabolic studies which demonstrate that low carbohydrate diets bestow any benefits on persons with diabetes.

High carbohydrate diets have been used in some Western countries and in India and Japan to treat patients with diabetes. The available data indicate that high carbohydrate diets lead to improved glucose metabolism and lower insulin requirements for most persons with diabetes. These high carbohydrate diets are accompanied by lower serum cholesterol and triglyceride values than observed when high fat diets are used to treat diabetes. Recent evidence suggests that dietary fibre intake is associated with improved glucose metabolism, lower insulin requirements, and lower serum lipid values than observed on low fibre diets.

High carbohydrate, high fibre diets are accompanied by dramatic reductions in insulin requirements and in serum lipids in selected patients with diabetes. These regressions in diabetes have been sustained for over three years in patients who have successfully followed these modified diets. These observations suggest that fat restricted diets providing generous quantities of complex carbohydrate and dietary fibre may have therapeutic usefulness for most adults with diabetes. High carbohydrate, high fibre diets may slow the progression of arteriosclerotic vascular disease in individuals with diabetes.

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References

Anderson, J. W. (1977a). Effect of carbohydrate restriction and high carbohydrate diets on men with chemical diabetes. *American Journal of Clinical Nutrition*, **30**, 402–408

Anderson, J. W. (1977b). High polysaccharide diet studies in patients with diabetes and vascular disease. *Cereal Foods World*, **22**, 12–15

Anderson, J. W. (1979). High carbohydrate, high fiber diets for patients with diabetes. *Proceedings of Fourth International Symposium on Early Diabetes*. Plenum, New York

Anderson, J. W. and Chen, W. L. (1979). Plant fiber. Carbohydrate and lipid metabolism. *American Journal of Clinical Nutrition*, **32**, 346–363

Anderson, J. W., Lin, W-J. and Ward, K. (1978). Composition of foods commonly used in diets for persons with diabetes. *Diabetes Care*, **1**, 293–302

Anderson, J. W. and Ward, K. (1978). Long term effects of high carbohydrate, high fiber diets on glucose and lipid metabolism: A preliminary report on patients with diabetes. *Diabetes Care*, **1**, 77–82

Anderson, J. W. and Ward, K. (1979). High carbohydrate, high fiber diets for insulin-treated men with diabetes mellitus. *American Journal of Clinical Nutrition*, **32**, 2312–2319

Anonymous (1972). Food and Nutrition Board, National Academy of Science—National Research Council and Council on Food and Nutrition, American Medical Association, Diet and coronary heart disease—A joint statement. *Preventive Medicine*, **1**, 559–561

Anonymous (1975). National Commission of Diabetes. Report to the Congress of the United States. *Diabetes Forecast*, **28** (Supplement 1), 1–60