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Prospective comparison of modified-fat–high-carbohydrate with standard low-carbohydrate dietary advice in the treatment of diabetes: one year follow-up study

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1. A prospective randomized study of two dietary regimens has been started in newly-diagnosed diabetics to determine their effect on circulating metabolites and on diabetic complications.

2. During the first year of treatment the fasting plasma glucose concentrations on both the low-carbohydrate diet and the high-carbohydrate, modified-fat (MF) diet showed a similar decrease.

3. Plasma cholesterol showed a sustained decrease only in patients recommended a MF diet. Transient changes in plasma triglyceride concentrations occurred in patients on both dietary regimens.

4. Increased plasma cholesterol levels are associated with atheromatous disease which is common in diabetics in Europe and North America. A MF diet may therefore have an advantage in that it lowers the plasma cholesterol as well as being effective in lowering the plasma glucose.

A diet low in carbohydrate is usually recommended to diabetic patients in westernized countries. However, Japanese (Hirata, Nakamura & Kaku, 1970), Trappists (Groen, Jijong, Koster, Willebrande, Verdanck & Pierlort, 1962), and Yemenite Jews (Brunner, Altman, Nelken & Reider, 1964) usually consume diets high in carbohydrate and no change in this pattern is recommended for diabetic patients. In these communities serum lipid levels tend to be lower than in westernized countries, and ischaemic heart disease is less frequent in both diabetics and the general population (Groen *et al.* 1962; Brunner *et al.* 1964; Fukui, Masaki, Fujita and Jakahata, 1970). Increased serum lipid levels, a common finding in diabetics (Hayes, 1972), are known to predispose (in a general population) to the premature development of ischaemic heart disease (Carlsön & Böttiger, 1972). A low-cholesterol, high-carbohydrate diet recommended to thirty American insulin-dependent diabetics resulted, after 1 year, in a significant decrease in both cholesterol and triglyceride levels, though there was no appreciable weight change (Stone & Connor, 1963), and a high-carbohydrate diet has been shown to improve glucose tolerance when diabetes is chemically mild or already under treatment (Brunzell, Larner, Hazzard, Porte & Bierman, 1971; Brunzell, Larner, Porte & Bierman, 1974).

We have started a prospective study in newly-diagnosed diabetics who are randomized on entry between advice on a standard low-carbohydrate (LC) diet, or on a diet containing an average amount of carbohydrate but in which the fat component has been modified in a way expected to reduce plasma cholesterol levels. We report here the findings in those patients who have been followed for 1 year and who did not require therapy with either insulin or oral hypoglycaemic agents during this time.

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Table 1. *Composition (g/kg) of the low-carbohydrate (LC) and modified-fat, high-carbohydrate (MF) diets recommended to newly-diagnosed diabetic patients*

(Values in parentheses indicate the contribution to total dietary energy (%))

	LC		MF	
Energy (MJ (kcal))	6·3 (1500)		6·3 (1500)	
Protein	75	(20)	75	(20)
Carbohydrate	150	(40)	203	(54)
Fat: Total	67	(40)	43	(26)
Saturated and monounsaturated fatty acids (S)	46	(28)	16	(10)
Polyunsaturated fatty acids (P)	21	(12)	27	(16)
P:S	0·5		1·7	

METHODS

Subjects

Newly-diagnosed diabetics aged 65 years or under attending the Radcliffe Infirmary Diabetic Clinic, Oxford, were admitted to the study, provided that they were willing to co-operate, were not suffering from any co-existent major illness, and were not thought to require immediate insulin therapy. The presence (or past history) of any other endocrine disease, myocardial infarction or neurological deficit following a cerebrovascular accident, precluded admission, as did the presence, but not a past history, of liver disease. On admission to the study, an intravenous glucose tolerance test (20 g/m^2 body surface) was performed after 3 d on a diet containing at least 200 g carbohydrate/d. All except two of the patients reported had K_G (glucose disappearance after an intravenous glucose tolerance test) values below 1·0, and of these one had a fasting blood glucose of 6·7 mmol/l and the other, with a fasting value of 5·5 mmol/l, had a blood glucose of 10·5 mmol/l at 1 h in a previous 50 g oral glucose tolerance test.

Diets

Patients were randomly allocated to receive one of two types of dietary advice. One regimen was a classical LC diet, while the other was aimed at restriction of cholesterol, reduction of total fat and an increase in the proportion of polyunsaturated fatty acids (high-carbohydrate, modified fat, MF). The composition of two sample diets is given in Table 1. The MF diet is only 'high carbohydrate' by comparison with the LC diet. Carbohydrates provide around 55% of total energy, which many might regard as average rather than high. Patients were encouraged to eliminate simple sugars as far as possible, but special attention was not given to dietary fibre, thus various complex carbohydrate foods predominated. The recommended energy content is determined from the excess above ideal body-weight (Metropolitan Life Insurance Co., 1959): an 8·4 (2000), 6·3 (1500) or 4·2 (1000) MJ (kcal) diet being prescribed if the patient is respectively more than 10, 20 or 30% overweight. The proportion of total energy provided by the various food constituents naturally tended to vary slightly in the diets of differing energy content, e.g. in the 4·2 MJ diet the amount of carbohydrate in the two diets was identical and the principal difference was in the P:S ratio.

Patients were seen in the clinic after 1 month and then at 3-monthly intervals when they again talked with the dietitian. Dietary advice was then repeated. Patients varied in their co-operation, but the report includes all subjects who entered the study. It is the impression of the authors that the majority of the patients did not experience appreciably more difficulty with the MF than the LC diet. Patients were re-tested at 1 month and again after 1 year.

Analytical methods

Of the various measurements made, those reported here are fasting concentrations of plasma cholesterol, triglyceride and insulin and glucose. The following established laboratory

Table 2. *Details of newly-diagnosed diabetic patients included in the study of low-carbohydrate (LC) and high-carbohydrate, modified-fat (MF) diets*†

	LC	MF
No. of patients: Total	54	39
♂	32	20
♀	22	19
Age (years): Mean	53	50
Range	22–65	24–65
Starting wt (kg): Mean	76·4	82·2
Range	51–99	56–114
Change in wt after 1 month (kg): Mean	−3·3*	−2·7*
Range	+1−−8	+3−−10
Change in wt after 1 year (kg): Mean	−3·8*	−4·6*
Range	+8−−20	+3−−33

Difference between initial weight and weight at sampling times was statistically significant: * $P < 0.001$.
† For details see Table 1 and p. 358.

Table 3. *Fasting plasma cholesterol and triglyceride concentrations of newly-diagnosed diabetic patients recommended low-carbohydrate (LC) and high-carbohydrate, modified-fat (MF) diets*§

(Mean values with their standard errors for fifty-four patients on LC diet and thirty-nine patients on MF diet)

	MF		LC	
Cholesterol (mmol/l)	Mean	SE	Mean	SE
On entry	6·2	0·20	6·5	0·21
After 1 month	5·2	0·19*	6·2	0·17
After 1 year	5·6	0·21*	6·3	0·19
Triglyceride (mmol/l)				
On entry	1·59	0·12	1·69	0·12
After 1 month	1·40	0·10†	1·36	0·08‡
After 1 year	1·59	0·12	1·59	0·11

Difference between initial cholesterol and cholesterol concentrations at sampling times were statistically significant: * $P < 0.001$.
Difference between initial triglyceride and triglyceride concentrations at 1 month were statistically significant: † $P < 0.02$, ‡ $P < 0.01$.
§ For details see Table 1 and p. 358.

methods were used for the analyses: cholesterol, Searcy & Bergquist (1960); glucose, glucose oxidase (gum guiac) method of Technicon Instruments Co. Ltd; triglyceride, Eggstein & Kreutz (1966); insulin, Albano, Ekins, Maritz & Turner (1972). The statistical significance of differences was tested by the Wilcoxon test (Siegel, 1956).

RESULTS

The number of patients included in the study is described in Table 2 which also gives the changes in body-weight which occurred during the year of study. Many were obese; the extent of over-weight (% over ideal body-weight) was 28 in the group started on the LC diet and 37 amongst those on the MF diet, and the difference between the two groups at entry was statistically significant ($P < 0.02$). A significant and sustained decrease in body-weight occurred equally in both groups.

Fasting plasma cholesterol and triglyceride levels are shown in Table 3. Mean levels of

Table 4. *Fasting plasma glucose and insulin of newly-diagnosed patients recommended low-carbohydrate (LC) and high-carbohydrate, modified-fat (MF) diets*†

(Mean values with their standard errors for fifty-four patients on LC diet and thirty-nine patients on MF diet)

	MF		LC	
Glucose (mmol/l)	Mean	SE	Mean	SE
On entry	12·5	0·72	10·8	0·58
After 1 month	8·4	0·58*	8·8	0·49*
After 1 year	7·6	0·51*	7·4	0·47*
Insulin (μunits/ml)				
On entry	10·8	1·11	11·0	0·99
After 1 month	10·9	0·93	11·9	1·85
After 1 year	10·9	1·15	11·2	0·98

Difference between glucose at entry and glucose concentrations at sampling times were statistically significant: * $P < 0{\cdot}001$.

† For details see Table 1 and p. 358.

both lipids were very similar in the two groups at entry. After 1 month triglyceride levels had decreased significantly on both diets, but by 1 year they had reverted to the initial levels. On the MF diet, cholesterol levels showed a sustained decrease and, at 1 year, although slightly higher than after 1 month, were still significantly lower ($P = 0{\cdot}01$) than the levels observed on the LC diet. No significant change in cholesterol levels occurred on the LC diet.

Fasting plasma glucose and insulin levels are given in Table 4. Glucose levels on entry were higher in patients on the MF diet ($P = 0{\cdot}05$) but at 1 month and 1 year the levels had decreased appreciably and at both these sampling times there was no difference between the two dietary treatment groups. Mean insulin levels did not change significantly during the period of observation.

The changes in plasma glucose and lipid levels did not correlate with the changes in body-weight nor with starting weight, expressed either in absolute terms or relative to ideal body-weight. The results were examined separately for sex differences and with one exception (females on the MF diet did not show the significant decrease in triglyceride at 1 month shown by males) the trends shown for men and women did not differ appreciably.

DISCUSSION

Although ischaemic heart disease is the commonest cause of death among diabetics in western societies, it is not clear whether the relationship between hyperglycaemia and ischaemic heart disease is causal or mediated, for instance, by the hyperlipidaemia often associated with diabetes (Abrams, Jarrett, Keen, Boyns & Crossley, 1969). In studies of the total population of an area, fasting serum cholesterol concentration has emerged as an important predictor of subsequent development of ischaemic heart disease (Kannel, Castelli, Gordon & McNamara, 1971). Triglycerides have been investigated less intensively, but a recently published study suggests that they exert an effect independent of cholesterol (Carlsön & Böttiger, 1972). Pima Indians show a very high frequency of diabetes but have low serum cholesterol levels and among them coronary disease is not more frequent in the presence than in the absence of glucose intolerance (Bennett, Burch & Miller, 1971). The relevance of satisfactory diabetic control (as measured by fasting plasma glucose or response to a glucose load) to subsequent development of ischaemic complications has not been adequately studied.

In 1935, Himsworth first suggested that diets low in carbohydrate and relatively high in

fat were associated with an increased incidence of diabetic deaths when compared with those high in carbohydrate and low in fat (Himsworth, 1935). In non-diabetic subjects, lowering of cholesterol by dietary means appears to reduce the incidence of cardiac events (Weinsier, Seeman, Herrara, Assal, Soeldner & Gleason, 1974). In the present study different metabolic responses occurred according to dietary advice. The MF diet caused a sustained lowering of the plasma cholesterol, whereas the usual LC diet had no effect at 1 year on either plasma cholesterol or triglyceride. Both diets caused only a transient decrease in the plasma triglyceride. This was more marked in the LC diet, and the temporary response may have been the reverse of the temporary increase of plasma triglyceride to a high-carbohydrate diet.

In one respect, the purely practical, it is not important to know how closely patients realized their dietary advice, and doubtless there would have been great discrepancies between food recommended and food eaten (Tunbridge & Wetherill, 1970). However, two important questions are unanswered by our results: was the cholesterol fall on LF advice related to the extent of over-all adherence to that advice? Did patients adhere equally to the three main features of the LF advice, namely, reduction in proportion of energy from fat, reduction in dietary cholesterol, and increase in the fatty acid ratio, polyunsaturated: saturated? We can only remark that the reduction in cholesterol did not correlate with the decrease in weight, one measure of dietary adherence. It would be naive to believe it possible by interviews with dietitians or random home visits (which were not carried out during the course of the present study) to obtain more than an improved indication of the extent of dietary adherence. Incarceration of the patients in a specialized hospital ward for 1 year would produce more precise results but would defeat the whole object of the study: a trial of dietary advice under everyday circumstances of diabetic patients.

These findings differ from those recently reported by Weinsier *et al.* (1974) who showed no difference in plasma lipid levels in patients recommended high-carbohydrate and LC diets, but the two investigations are not strictly comparable. The American study was small, patients were not newly diagnosed as diabetic, and none were obese. Their advice about dietary fat differed: thus, on both high-carbohydrate and LC diets, the ratio, animal fats:vegetable fats was aimed to be between 0·5 and 1·0. We gave advice about the nature of the fats only to those on the MF diet and considered the proportion of polyunsaturated fats rather than that of vegetable fats.

The two diets in our study were similarly effective in reducing weight and plasma glucose. Thus the MF diet appears to have an advantage in lowering the plasma cholesterol and no disadvantage as far as fasting glucose control is concerned. These results also provide evidence which suggests that energy restriction may be the most important factor in achieving control of glucose concentrations in newly-diagnosed diabetics. They do not support the conclusions of Hadden and his co-workers (Hadden, Montgomery, Skelly, Trimble, Weaver, Wilson & Buchanan, 1975) or Wall and his co-workers (Wall, Pyke & Oakley, 1973), who considered that carbohydrate restriction is the determining factor, but the findings support their view that weight loss does not determine change in glucose. One year is too short a period from which to make any definite long-term assessment of a diet. However, we hope that such observations, maintained prospectively, will help in the assessment of plasma glucose, triglyceride and cholesterol as relative risk factors in the occurrence of ischaemic heart disease in diabetics, and thus help to establish more satisfactory dietary advice for patients with this disease.

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REFERENCES

Abrams, M. E., Jarrett, R. J., Keen, H., Boyns, D. R. & Crossley, J. N. (1969). *Br. med. J.* i, 599.
Albano, J. D. M., Ekins, R. P., Maritz, G. & Turner, R. C. (1972). *Acta Endocr.* **70**, 487.
Bennett, P. H., Burch, P. A. & Miller, M. (1971). *Lancet* ii, 125.
Brunner, D., Altman, S., Nelken, L. & Reider, J. (1964). *Diabetes* **13**, 268.
Brunzell, J. D., Larner, R. L., Hazzard, W. R., Porte, D. & Bierman, E. L. (1971). *New Engl. J. Med.* **284**, 521.
Brunzell, J. D., Larner, R. L., Porte, D. & Bierman, E. L. (1974). *Diabetes* **23**, 138.
Carlsön, L. A. & Böttiger, L. E. (1972). *Lancet* i, 865.
Eggstein, M. & Kreutz, F. H. (1966). *Klin. Wschr.* **44**, 262.
Fukui, I., Masaki, K., Fujita, F. & Jakahata, J. (1970). In *Diabetes Mellitus in Asia*, p. 130 [S. Tsuji and M. Wada, editors]. Amsterdam: Excerpta Medica.
Groen, J. J., Jijong, K. B., Koster, M., Willebrande, A. F., Verdanck, G. & Pierlort, M. (1962). *Am. J. clin. Nutr.* **10**, 456.
Hadden, D. R., Montgomery, D. A. D., Skelly, R. J., Trimble, E. R., Weaver, J. A., Wilson, E. A. & Buchanan, K. D. (1975). *Br. med. J.* iii, 276.
Hayes, T. M. (1972). *Clin. Endocr.* **1**, 247.
Himsworth, H. P. (1935). *Clin. Sci.* **2**, 117.
Hirata, Y., Nakamura, Y. & Kaku, V. (1970). In *Diabetes Mellitus in Asia*, p. 216 [S. Tsuji and M. Wada editors]. Amsterdam: Excerpta Medica.
Kannel, W. B., Castelli, W. P., Gordon, T. & McNamara, P. M. (1971). *Ann. int. Med.* **74**, 1.
Metropolitan Life Insurance Co. (1959). *Statistical Bulletin*, vol. 40 (November–December), pp. 1–4.
Searcy, R. L. & Bergquist, L. M. (1960). *Clinica chim. Acta* **5**, 192.
Siegel, S. (1956). *Non Parametric Statistics for Behavioural Sciences*, pp. 75, 116. New York: McGraw-Hill.
Stone, D. B. & Conner, W. E. (1963). *Diabetes* **12**, 127.
Tunbridge, R. & Wetherill, J. H. (1970). *Br. med. J.* ii, 78.
Wall, J. R., Pyke, D. A. & Oakley, W. G. (1973). *Br. med. J.* i, 577.
Weinsier, R. L., Seeman, A., Herrara, M. G., Assal, J. P., Soeldner, J. S. & Gleason, R. E. (1974). *Ann. int. Med.* **80**, 332.

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