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Review Articles

Diet and Diabetes

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The observation that diet is the fundamental element of therapy in most cases of non-insulin-dependent diabetes is perhaps the only uncontroversial conclusion of the University Group Diabetes Program, which cast some doubt on the value of at least two drugs widely used in the treatment of diabetes [1]. The role of diet in the aetiology and management of insulin-dependent diabetes is less clear. Other environmental causes and a genetic predisposition almost certainly take precedence over nutritional factors in the aetiology. The role of diet in the treatment of insulin-dependent diabetes has recently been reviewed [2] and this brief review therefore deals principally with the non-insulin-dependent type.

Historical and Epidemiological Observations

Dietary advice has been given to diabetic patients for close to half a century and perhaps the first detailed diabetic diet sheet was introduced by Rollo in 1797. He recommended a breakfast consisting of one and a half pints of milk and half a pint of lime water, together with bread and butter; pudding made of blood and suet to be eaten at noon; a dinner consisting in moderation of game or rancid old meats ("as far as the stomach may bear") and for supper a repeat of the breakfast menu. It is perhaps hardly surprising that this dietary advice never achieved widespread and lasting acceptance. However, during the 19th century a number of modifications were introduced and a diet which was low in carbohydrate and total energy content gradually evolved.

The three varieties of diabetic diets commonly recommended in the United States at the beginning of the insulin era have been reviewed by Fitz [3]. Both the 'Allen' and the 'Joslin' treatments consisted of an initial period of fasting or severe energy restriction and a maintenance diet which was aimed at keeping the patient in a state of subnutrition without progressive weight loss. The 'high fat' treatment was based on the concept that diabetes was characterised by a specific defect (viz. the inability to utilise glucose) rather than being a disease of total metabolism. The diets recommended were therefore very low in carbohydrate and between 75 and 85 per cent of the total energy was provided by fat. The maintenance diets were not as severely energy-restricting as those recommended by Allen and Joslin. In England, a modification of the 'high fat' dietary advice seems to have been given. At the London Hospital in 1931, the diabetic diet provided 15 per cent of the energy intake as carbohydrate, 17 per cent as protein, and 68 per cent as fat [4].

An early attempt to study the aetiological role of nutrition in diabetes was made by Himsworth in 1935 [5]. He compared the diet of a group of diabetic patients before the onset of the symptoms of their disease with that of a group of control patients matched for age and sex, and showed (using two methods of dietary analysis) that the diabetics chose diets of greater energy content and containing larger amounts of carbohydrate, protein and fat than the control group. The most striking change was in fat consumption which was increased out of proportion to the increase in the other dietary constituents. He had earlier observed [6] that the hyperglycaemia following oral administration of glucose was lower and less prolonged in normal people after a period on a high carbohydrate as compared with a high fat diet and therefore suggested that habitual ingestion by a potential diabetic of a diet containing a diminished proportion of carbohydrate may cause progressive impairment of glucose tolerance and insulin sensitivity with subsequent development of diabetes mellitus [5].

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In another epidemiological study, Himsworth compared food consumption data with mortality rates from diabetes mellitus in different countries and showed that in those countries with high death rates for diabetes, the diets contained a relatively low proportion of carbohydrate and high proportion of fat. He also pointed out the fall in diabetes mortality that occurred during the First World War and suggested that the dietary change at that time principally involved a reduction in the proportion of fat and increase in proportion of carbohydrate. He considered that race was not an important factor determining the incidence rates of diabetes since immigrant races tended to manifest the same incidence rates as the races of the host country when they acquired the dietetic preferences prevalent in the new land. Himsworth's data did not suggest that excessive consumption of sugar or alcohol played a part in the aetiology of diabetes [7].

A number of workers have pursued the epidemiological approach in order to study further the extent to which dietary factors may influence the incidence of clinical diabetes mellitus. Regrettably few studies distinguish patients with insulin-dependent from those with non-insulin-dependent diabetes. Excess energy consumption has emerged as the most consistent finding in all these studies. Cleave and Cambell have argued forcibly in favour of the hypothesis that excessive consumption of sugar and other refined carbohydrate have an important role in determining the prevalence of diabetes in a population [8]. The findings on which the conclusions of these workers are based may, however, be explained by the work of West and Kalbfleisch, who carefully studied the inter-relationship between nutritional factors and diabetes in twelve age-matched populations in different countries [9]. A positive correlation was found between diabetes prevalence and sugar consumption, but a very similar association was also present between fat intake and prevalence of the disease. Other workers have found that intake of sugar and fat in different population groups are closely related [10]. The most striking correlation in the investigation conducted by West and Kalbfleisch was between prevalence of diabetes and obesity ($r = 0.89$). In view of the positive association with sugar consumption it was also of interest that diabetes prevalence was negatively correlated with the amount of complex carbohydrate in the diet. Inter-racial differences in prevalence of diabetes were small when racial groups were matched for adiposity.

Using a case-control approach, Baird confirmed that diabetics consume significantly more in terms of total energy than their non-diabetic siblings, but found that the percentage of energy derived from each of the proximate constituents was the same for each group [11]. The observation has now been confirmed prospectively in the Israel Ischaemic Heart Disease Study in which an increased weight for height also correlated closely with subsequent development of diabetes but none of the individual food variables were related to diabetes incidence [12].

More recently Trowell has suggested that fibre-rich starchy foods are a protective factor with respect to diabetes and has shown that fluctuations in mortality rates from diabetes in the United Kingdom have closely followed crude fibre intake [13]. When attempting to interpret any data of this nature it is important to bear in mind that mortality statistics for diabetes may be unreliable since many deaths amongst diabetics result from the accelerated atherosclerosis associated with the condition. Atherosclerosis rather than diabetes often appears as the cause of death on the death certificate and published mortality statistics tend therefore to underestimate the true situation. Estimates of population food consumption should also be interpreted with great caution since these are frequently calculated from local production and imports after subtracting exports, and no account can be taken of wastage or of the quantities utilised for purposes other than consumption (for example, the amount of fat used in the manufacture of soap and candles) [14]. However, despite these reservations which apply to many epidemiological studies it would seem that an excessive energy intake is probably the principal epidemiological factor determining the prevalence of diabetes in a population; an observation supported by the rarity of diabetes in Pakistan and rural Uruguay where high carbohydrate and high fat diets are consumed respectively but where the populations remain lean [15]. This statement is not intended to suggest that genetic mechanisms are not relevant in non-insulin-dependent diabetes – the very high concordance rate in identical twins in fact suggests that inheritance is particularly important – but it may be that the condition only becomes apparent "at the population level" in the presence of a degree of overnutrition.

Metabolic Changes Associated with Diet

The metabolic link between body weight and glucose tolerance is not completely clear. Obesity is frequently associated with hyperinsulinism and a reduced tissue sensitivity to insulin which is reversed by weight reduction [16]. The effects on glucose tolerance and patterns of insulin secretion of altering the proportions of the different dietary constituents has been clarified by a number of recently published

investigations. In 1971, Brunzell and his co-workers confirmed Himsworth's earlier observation that glucose tolerance was improved and fasting plasma glucose levels lowered in normal subjects receiving high carbohydrate meals [17]. More recently they demonstrated that in diabetic patients treated with insulin or oral hypoglycaemic agents, fasting plasma glucose levels were lower on a high carbohydrate fat-free diet than on a basal diet consisting of 40 per cent fat and 45 per cent carbohydrate [18]. Among diabetics, only those who remained untreated had worsened glucose tolerance on fat-free high carbohydrate diets. Body weight remained constant during these dietary manipulations. The mechanism for the decrease in fasting glucose levels during administration of the high carbohydrate diet has been postulated as an increased insulin sensitivity, since there was no increase in basal insulin levels to account for the fall in glucose levels in the normoglycaemic subjects and no increase in the insulin dose in those who were insulin-dependent. Similar results have been obtained by other workers in man and in experimental animals.

Jenkins and his colleagues have shown that in diabetics the addition of pectin and guar to a test meal resulted in a reduced rise in blood glucose and insulin as compared with that seen when the meal was given without the addition of these unabsorbable plant polysaccharides [19]. They have also shown that supplementing diets with guar gum for one week decreased 24-hour glycosuria in insulin-dependent diabetics [20]. Miranda and Horwitz, using diets enriched with high cellulose bread for 10 days in eight adult diabetics, obtained a reduction of average postprandial, but not fasting, blood glucose levels [21]. Kiehm, Anderson and Ward found that by increasing the carbohydrate content (largely of cereal origin) of the diet from 43 per cent to 75 per cent it was possible to withdraw oral agents and reduce the dose of insulin [22].

On the other hand, low carbohydrate diets have been reported to worsen [23] or improve [24, 25] glucose tolerance. It seems likely that in some of these studies [24] the improvement in glucose levels was accounted for by the concomitant weight loss. Grey and Kipnis [25] studied six obese non-diabetic subjects who lost no weight during their dietary changes and showed changes similar to those described above when a basal diet was replaced by one high in carbohydrate. However, when the basal and high carbohydrate diets were compared with a low carbohydrate diet, fasting plasma glucose and insulin levels and oral glucose tolerance insulin responses in these patients were all lower on the low carbohydrate diet. The reasons for these differences are not apparent, but an important conclusion is that treated diabetic subjects do not appear to be adversely affected with regard to glucose-insulin homeostasis by diets high in carbohydrate.

The above conclusion is particularly relevant in view of the uncertainty as to how metabolic control, measured in terms of glucose tolerance, relates to the development of tissue damage [26]. Diabetic patients have a considerably increased risk of premature atherosclerosis and at the Joslin Clinic more than half the diabetic deaths have been ascribed to coronary arterial disease [27]. Elevated plasma cholesterol and triglyceride levels, common findings in diabetic patients [28], are known to predispose to the premature development of ischaemic heart disease in the general population [29]. Diets low in fat (or relatively high in polyunsaturated fat) have been shown to lower cholesterol levels in non-diabetic subjects and there is at least some evidence to suggest that such diets may have a beneficial effect in reducing the incidence of ischaemic heart disease [30].

Less information is available concerning the effects of such diets on diabetic patients. A low cholesterol, high carbohydrate diet, recommended to 30 American diabetics resulted, after a year, in a significant fall in both cholesterol and triglyceride levels, although there was no appreciable weight change [31]. (Only insulin-dependent diabetic patients of long standing were studied in this series.) A more recent comparison between "high" (60 per cent) and "low" (40 per cent) carbohydrate diets found no metabolic differences between the diets among the 18 non-obese diabetics studied [32], but interpretation of this study is difficult since both groups received instruction about the nature of the fats to be used; a factor which may well have affected plasma lipid levels.

In Oxford we have started a trial in which newly diagnosed diabetics have been randomised into two groups – one is given advice concerning a traditional low carbohydrate diet and the other a modified fat diet (relatively high in carbohydrate and low in fat, with a ratio of polyunsaturated to saturated fatty acids of 1.5 : 1). The energy allowance for individual patients is determined by their percentage over ideal body weight. During the first year of treatment plasma glucose concentrations showed a similar decrease on both regimens and plasma cholesterol showed a sustained decrease in patients recommended the modified fat diet [33]. High carbohydrate diets were initially thought to induce hypertriglyceridaemia in normal subjects [34], but while this may be true in the short term, fasting triglycerides tend to return to normal levels when such a diet is maintained for long periods of time [35]. Furthermore, high carbohydrate diets appear to lower plasma triglyceride levels when the levels are

examined over the entire 24 hours of the day in non-diabetics [36] and not to cause an increase in fasting triglyceride levels in insulin-treated diabetics given these diets for prolonged periods of time [31].

The above observations tend to suggest that a diet in which fat component has been modified and certain carbohydrates increased may have a more beneficial effect in terms of carbohydrate and lipid metabolism than the more traditional low carbohydrate diet usually recommended to diabetic patients, but further investigations are clearly required to confirm these effects. Furthermoore, a large prospective trial would be necessary to determine whether such dietary advice would prove beneficial in the prevention of atherosclerotic complications in diabetic patients. Epidemiological observations also suggest that such dietary advice may be of value to certain types of diabetics.

The study of Japanese migrants have yielded particularly useful information. The usual Japanese diet contains over 60% of the energy as carbohydrate and 16% as fat [37], and few changes are made in the diet of the Japanese diabetics other than to regulate the total energy intake and to restrict simple sugar. The total carbohydrate content of the Japanese diabetic diet (chiefly in the form of rice, bread and potato) is thus nearly twice that of diabetics in western countries. Various investigations have compared Japanese living in Japan with those in Hawaii where their diet is very similar to that of caucasian North Americans [38]. The prevalence of diabetes is nearly three times as great in men over the age of 40 in Hawaii as compared with Japan and incidence of ischaemic heart disease in known diabetics is appreciably greater in Hawaii, where cholesterol and triglyceride levels are also higher. The frequency of cardiovascular disease in the Japanese Hawaiian diabetics is identical to that in caucasian diabetics in Hawaii and similar to that observed in the Joslin Clinic [27]. Peripheral arterial disease and ketosis are also rare among Japanese diabetics, but the fact that they develop retinopathy [39] and renal failure at roughly the same rate as diabetics of Europe and North America and cerebrovascular disease perhaps more frequently suggests that the ideal diet for mitigating or preventing one of the vascular complications may not be optimal for another. Similar observations have been made concerning diabetics in the Trappist communities [40] and in Yemenite Jews [41].

Dietary Recommendations for Patients with Diabetes Mellitus

In the light of the epidemiological observations and results of the dietary experiments discussed above, it is of interest to consider briefly the dietary recommendations suggested by certain organisations concerned with the management of diabetes. The Committee on Food and Nutrition of the American Diabetes Association has described a series of dietary principles [42]. The single most important objective was considered to be the control of total energy intake in order to attain ideal body weight. The regularity of food intake (especially relevant to those patients receiving insulin therapy) was also stressed. Alteration of carbohydrate and fat content of the diabetic diet was considered in detail and clear advice given concerning the fact that disproportionate restriction of carbohydrate in the diet was not necessary. The Committee was unable to obtain uniform agreement as to the optimal proportion of carbohydrate and fat calories which should be recommended for the diabetic. They recognised that reduction of saturated fat and cholesterol were associated with a lowering of circulatory cholesterol in diabetic patients as in non-diabetic patients, but were not prepared to include in the recommendations an increased ingestion of polyunsaturated fat in view of the uncertainties regarding the long term effects of such dietary change. The recommendations stressed, also, the importance of individualisation, such as specific dietary advice for patients with specific metabolic abnormalities associated with the diabetic state. Thus an appropriate dietary recommendation presupposes prior testing for hyperlipidaemia in each diabetic patient, although in the majority of diabetics, blood lipid levels are within the range seen in a comparable non-diabetic population. Is it possible in 1980 to take these recommendations any further?

Insulin-dependent Diabetes

In insulin-dependent diabetes, dietary treatment is aimed at the supply of an adequate energy intake to ensure normal growth in children and to maintain ideal body weight in adulthood. The distribution of food throughout the day is important in order to avoid hypoglycaemia. The practical means by which these dietary principles may be achieved in young insulin-dependent diabetics has recently been reviewed by Baum and Maxwell [2]. Restriction of quickly absorbed monosaccharides and disaccharides seems likely to remain an important aspect of all diabetic diets. Carbohydrate exchanges are a time-honoured feature of diabetic diets and are probably still of value in insulin-dependent patients in whom their use helps to prevent hypoglycaemic attacks.

Many physicians tend to determine the insulin regime for patients and the diet then needs to be planned to fit the particular insulin. Often insulin-dependent diabetics complain bitterly about the rigidity of the meal pattern. Diabetologists (who are

often not particularly oriented towards diet) may need to be reminded therefore that the insulin regime could equally be tailored at least to some extent to suit dietary preference. This frequently improves compliance.

Probably the only really controversial aspect of the diet for insulin-requiring patients relates to the correct proportion of energy to be derived from carbohydrate and fat and a decision as to which type of carbohydrate is optimal. Many of the studies quoted earlier in this review have been of short duration or have used foods and diets not designed for long term outpatient use. We have recently compared the standard British low carbohydrate diet (around 40% energy from carbohydrate) with a diet in which carbohydrate, high in readily available and acceptable forms of cereal and tuberous vegetable fibre provided 60% total energy [43]. In order to achieve an isoenergetic comparison, fat intake was reduced from 40% to 25% total energy with a ratio of polyunsaturated to saturated fatty acids of 1 : 1. Fasting and preprandial blood glucose levels were appreciably lower on the experimental diet. (The postprandial levels were not significantly different.) Furthermore levels of total and low density lipoprotein cholesterol were reduced and the ratio of high density lipoprotein to total cholesterol increased. Thus several measures of lipid and carbohydrate metabolism were apparently shifted in a favourable direction by a diet which the majority of patients found acceptable.

The experimental dietary period was 6 weeks and for long term use total carbohydrate would probably need to be decreased slightly or some of the carbohydrate provided as mono- or disaccharides since several of the participants in the trial did feel that some of the meals were rather too filling. Although the ratio of polyunsaturated to saturated fat was somewhat higher than in the average British diabetic or usual diet, the fact that total fat was reduced means that the total amount of polyunsaturated fat ingested would not be large enough to cause concern amongst those worried about possible long term adverse effects of a high polyunsaturated fat intake [44].

The experimental diet did not influence postprandial glucose levels to any appreciable extent. The gel-forming fibres which are now well known to reduce postprandial hyperglycaemia are unfortunately not yet available in forms which are acceptable to the majority of patients in the long term. We are at present testing the effect of leguminous carbohydrate which may be more like the gel-forming fibres than the cereal and vegetable fibres tested thus far. It is important to establish to what extent absorbable carbohydrate rather than dietary fibre had contributed towards the improved level of diabetic control observed on the high carbohydrate diet. For the present we feel confident in recommending a diet in which carbohydrate provides between 55% and 60% total energy and consequently less fat than the current diabetic diet prescription. The circumstantial evidence seems to us to be good enough to recommend that polyunsaturated fat should comprise about 50% of total fat [45]. We are not yet certain about the optimal carbohydrate source but until more data are available it would seem reasonable to advise the types we have used in our experimental diets thus far.

Non-Insulin-dependent Diabetes

With regard to patients who do not require insulin, the main objective of dietary management is to achieve and maintain ideal body weight. The old maxim "it does not matter what you eat as long as you do not eat it" is probably correct for a large proportion of patients and perhaps the most helpful research for the future would concern new methods of weight reduction. Nevertheless one does need to consider also the optimal distribution of energy from the various proximate food constituents. We have carried out a similar comparison to that described above in insulin dependent patients and although the results were a little less striking an identical trend was apparent [46]. Thus it appears that even in this group of patients in whom obesity is so common, carbohydrate restriction is unnecessary; though once again the optimal carbohydrate sources remain to be determined.

Current Diabetic Clinic Practice

In the light of these studies, the findings of Thomas et al. [46] are of considerable interest. They surveyed the dietary advice given at diabetic clinics (and certain general medical and paediatric clinics) throughout Britain during 1973 and found that the majority of clinics recommended to diabetics a diet which was low in carbohydrate (around 40 per cent of total energy). Dietary fat was usually not restricted except in overweight non-insulin-dependent diabetics and fewer than 10 per cent of all clinics routinely recommended replacement of saturated by polyunsaturated fats. The majority of clinics would have recommended lipid-lowering treatment by diet and/or drugs had they known a patient to be hypercholesterolaemic but in only around 30 per cent of clinics were patients routinely screened for high serum cholesterol.

West has recently reviewed the attitudes of diabetic patients towards the dietary advice given them [48]. The findings of the National Health Survey in America showed that 22 per cent of diabetics stated

that "they were never given a diet for their diabetes" and another 25 per cent said that "they had received a diet but did not follow it". Only 53 per cent of this representative group of American diabetics indicated that they followed a prescribed diet [49] and the situation in Britain appears to be very similar [50]. The reasons for the failure of many diabetics to understand and follow their diet prescriptions are undoubtedly complex. Physicians tend to underestimate the difficulties of developing, implementing and adjusting a diet prescription that is both acceptable and effective over a long period of time. Perhaps even more important though is the fact that there is still disagreement among the experts over certain principles of diet therapy. With no less than 150 different printed diet sheets currently in use in the United Kingdom [4] there must be confusion when a diabetic patient moves from one area to another. New dietary recommendations are urgently required. Although more research is still required some of the suggestions here might provide the basis.

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