Nutrition and Diabetes

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The history and epidemiology

The use of low carbohydrate diets in the management of diabetes persisted after the discovery of insulin until well into the 1970s. The recognition of different types of diabetes scarcely altered the approach. Then, efforts began to incorporate knowledge about improved glucose tolerance on high carbohydrate diets into overall nutrition management. The problem was that, in insulin deficiency or insulin resistance, on a particular occasion, a greater oral glucose load led to a greater glycaemic response. Accommodation of these two considerations was reached by encouraging the larger quantities of carbohydrate to be had with a spread throughout the day.

At the same time, the emergence of dietary guidelines to reduce the major chronic diseases of industrialized societies also encouraged a relatively greater intake of plant food and a reduction in saturated animal fat in the community at large. This approach seemed not to be particularly different to the emerging nutritional management for diabetes. For those with insulin-dependent diabetes (IDD), it seemed that a preferred food pattern could be determined on general nutritional grounds and insulin tailored around that pattern. This became more possible with twice daily use of medium and short-acting insulins and, later, the use of insulin pens. Short-acting insulin delivered from a cartidge pen just prior to a meal meant more flexibility in meal times as well. For those with non insulin-dependent diabetes (NIDD), however, the need to decrease insulin resistance by nutritional means and to avoid glucose overload at a particular time remained important. Where it was possible to reduce body fatness in NIDD accompanied by obesity, this remained the best option.

Not only the degree of body fatness[1,2], but its distribution would appear to determine the expression of NIDD[3]. With this background, and the present intensity of research in the area, we are poised for a new level of both sophistication and simplification in the nutritional management of diabetes.

Nutritional factors may also affect the development or expression of diabetes independent of body fatness. The international comparisons of food intake and the prevalence of diabetes by Kelly West raised doubts about the merits of a low carbohydrate intake in avoidance of diabetes[1,2]. Such observations have implications for prevention.

More recent detailed scrutiny of the food intake patterns of groups within countries at different risk of diabetes

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have stimulated enquiry into the relative importance of food intake as opposed to other lifestyle factors[4]. Such comparisons include urban and rural and one ethnic group with another. Bihari Raheja has considered the differences in food usage of Indian groups at lower and higher risk for diabetes and for principally macrovascular complications[5]. Although the low risk diet appears to have characteristics evident in other comparisons, such as a high pulse or legume consumption, and a low saturated fat consumption, the kind of dairy product used in those at low risk is different with relatively more yogurt. There is relatively more use of fresh, whole fruit as opposed to juice and a greater use of onions and garlic and of condiments. What may matter is the total food pattern and it is conceivable that there may be more than one food pattern conducive to low risk.

Whilst overnutrition may allow the expression of diabetes, so also can malnutrition. Malnutrition-related diabetes mellitus (MRD) has two principle forms, fibrocalculous pancreatic diabetes and protein-deficient pancreatic diabetes. The former has been associated with high cassava consumption and the consequent intake of cyanogenetic glycosides[6,7].

Alcohol abuse and proneness to iron storage disease are yet other ways in which nutrition is known to contribute to the development of diabetes.

In respect of IDDM, despite its increasing incidence, a nutritional contribution is by no means clear.

More than food?

Inappropriate food intake is often regarded as the basis of unacceptable blood glucose control when other factors may be responsible or more important[4]. Changes in physical activity would be an example[4]. Emotional stress is difficult to measure and sometimes clinically obscure and, yet, may, through the autonomic nervous system and release of hormones counter-regulatory to insulin, contribute to hyperglycaemia[8].

Moreover, good social networks may ameliorate the potentially adverse effects of stress on regimen adherence[9]. Too complex a dietary regimen may be counter-productive to patient survival in NIDD[10].

Food and the pathogenesis of diabetes

The ways in which food intake may contribute to the development of diabetes, on present understanding, can be summarized as follows :

(1) Positive energy balance, reflected in obesity[11,12].

(2) Macronutrient disproportion, with too high a saturated fat intake and too low a carbohydrate and dietary fibre intake[13,14,15,16,17,18]. However, these dietary characteristics may, in part, be markers for other food factors of importance. Moreover, no adequate prospective data on the development of diabetes mellitus in relation to such food intake patterns are available. The data that we draw on are basically cross-sectional.

(3) Alcohol abuse probably accounts for a few percent of the population of those with diabetes in developed countries. The mechanisms include pancreatic, including beta cell damage, hepatic cirrhosis and alcohol-related iron storage disease.

(4) Micronutrients

Zinc deficiency has been

regarded as a possible contributing factor to development of diabetes in association with malnutrition, and limited animal data support this view[19].

Chromium deficiency has been shown to contribute to the development of diabetes in association with prolonged parenteral nutrition[20].

(5) Food toxins

The food toxin most considered as an aetiological agent in the development of diabetes is cyanide from cassava (see above). However, it should be noted that streptozotoxin, which is a beta-cell toxin, is produced by soil micro-organisms and may be a prototype for other such factors in food.

An Icelandic study of the development of diabetes has related some cases to the consumption of cured meat at a vulnerable stage of pregnancy amongst the mothers of those with diabetes[21,22]. There has, however, been much debate about the validity of these observations.

Food factors and management of blood glucose

The food factors which may be of value in the management of blood glucose are :

(1) Physical properties (viscosity and structure)

(2) Components

i. Nutrients

ii. Non-nutrients

It became clear in 1977 and 1978 that the notion that a distinction between simple sugars and starches accounted for different effects of food carbohydrate on blood glucose was inadequate. Wahlqvist *et al.* demonstrated that glucose containing molecules, whether mono-, di-, penta- or polysaccharide had the same effect on blood glucose[23]. Crapo *et al.* showed that a variety of foods containing the same amount of total carbohydrate had quite different effects on blood glucose and on insulin response, so that factors other than the carbohydrate must have been important in determining these responses[24]. Jenkins *et al.* demonstrated that some isolated dietary fibre types altered glucose tolerance on the basis of viscosity[25].

It does, however, seem that one of the most important properties of food which creates a different glycaemic outcome is its physical structure. By the creation of different particle sizes, grains of various kinds have been shown to have different effects on blood glucose[26,27]. However, this is not as evident with legumes[28,29]. These differences, or the lack of them, have been observed in relation to the cracking or grinding of grain or the blending of legumes. Cooking, however, may further modify starch granules, thereby increasing the glycaemic response[30].

Dietary fibre, as found in food, may not contribute in a chemical sense to glycaemic response in healthy subjects[31, 32] or in diabetic patients[31, 33]. This is not to say that foods which include dietary fibre, or have a different kind of dietary fibre, may not have altogether different effects on blood glucose in healthy subjects and diabetic patients[34,35]. Efforts to make this distinction between effects of dietary fibre on the one hand and absorbable carbohydrate on glycaemic response on the other have so far been confined to acute studies. The studies have been made difficult by the need to produce meals comparable in fat and carbohydrate, with the same monomeric sugar spectra; the 1981 and subsequent papers of Simpson *et al.* attempt to achieve this objective[31].

There is no question that dietary

fibre isolates, such as cereal brans (wheat)[36], oat bran[37] and gums[25], can favourably alter blood glucose[38]. Arguably, this is more food pharmacology than physiology.

It has been known for much longer that the macronutrients fat and protein can affect the glycaemic response to food[33,39,40,41].

It is very likely that a number of other non-nutrient compounds in food are biologically active in respect of the glycaemic response. These may included enzyme inhibitors, lectins and polyphenols[42].

The sum total of both physical factor and chemical properties of food is a diversity of glycaemic responses for the same amount of carbohydrate. The general hierarchy of glycaemic indices, usually with reference to white bread as 100%, is, from highest to lowest, root vegetables, breakfast cereal, grain and cereal products, vegetables (other than root and legumes), snack food, biscuit, fruit, legumes and dairy products. Some of the legumes have the lowest glycaemic indices of all. With such a vast range of glycaemic indices from 4 or 5 to 100% (or even a little more for pure glucose or maltose), dietary counselling for diabetic patients cannot afford to restrict itself to the consideration of carbohydrate[43,44].

Another important consideration is that there is a considerable inter-individual variation in glycaemic index, as shown presently for healthy subjects by Thorburn, Brand and Truswell[44]. Jenkins and colleagues (personal communication), however, have demonstrated that the intra-individual variation in glycaemic index in those with diabetes is small. What this means is that individual counsel in respect of food response is desirable. However, there would still appear to be justification in shifting the glycaemic response distribution curve for the diabetic population towards the lower zone; clearly some patients will benefit more than others from this approach as far as glycaemic response is concerned, although there are likely to be wider nutrition applications of advantage to relatively more individuals.

Meal patterns and management of blood glucose

When the overall use of foods of either low or high glycaemic index is compared for their impact on blood glucose across the day, the prevailing blood glucose is lower with lower glycaemic index foods[43]. In the study of Jenkins *et al.* which looked at day-long responses, emphasis was placed on the lower glycaemic index foods, such as rye bread, oat bran, bulgur (cracked wheat), beans, barley and pasta or on higher glycaemic foods such as wheat breads, potato, rice and breakfast cereals, with fruit, milk, baked goods and sucrose being left much the same. More recently, a prolonged three month cross-over study has been carried out by Truswell *et al.* (personal communication) which shows that the improvement in blood glucose control is maintained when there is preference for low glycaemic index foods.

Although it has quite reasonably been assumed that distribution of carbohydrate containing food across the day may be better than having more at once in the management of diabetic patients, especially those with type II, where there are problems of sensitivity to endogenous insulin, the proposition has not been formally tested[45]. We recently demonstrated that a main evening meal gives a better overall

glycaemic control than does an even distribution of energy and carbohydrate between main 3 meals and between 3 snacks, at least for those with NIDD[45].

Acute versus chronic effects of foods on blood glucose

The continued use of high carbohydrate-high dietary fibre containing foods progressively induces a decrease in fasting blood glucose which reaches a nadir after about two weeks[46]. The response above this changed baseline glucose may not be different after two weeks (Simpson and Wahlqvist, unpublished observations). The reduced baseline presumably represents a progressive reduction in overnight gluconeogenesis with use of relatively more unrefined carbohydrate type foods. It is most important to make the distinction between the acute and longer term affects of foods on overall blood glucose control.

Moreover, foods whose lower glycaemic index is attributable to their fat content may have an adverse effect on insulin sensitivity and on subsequent meal responses[40].

Fat type and glycaemic management

There has been much interest in the protection of fish consumption against ischaemic heart disease[47]. Such a role of fish may in part be due to its favourable effects on platelet function and on very low density lipoprotein (VLDL) cholesterol triglyceride, on account of its omega-3 fatty acid content[48]. However, recent work by Glauber *et al.* where fish oil (18 g/d) was fed for 1 month, to men with NIDD, demonstrated a deterioration in fasting glucose and glucose response to a mixed meal[49]. These effects were attributable to increased glucose production and decreased insulin responses to mixed meals and to glucagon. Despite these findings, recent studies show that healthy and diabetic fish-eaters have better arterial wall characteristics than do their non or low fish-eating counterpart[50]. Ultimately, it must be more important to know health outcomes rather than blood glucose responses. It may be important that the insulin responses are less with fish oil, in terms of likelihood of macrovascular disease; or it could be that other effects of fish oil, on platelet function, or effects of yet other components of fish, may mediate favourable biological responses sufficient to offset adverse glycaemic effects.

There has been much discussion in recent times about whether it may be possible to achieve lower plasma triglyceride concentrations and higher high density lipoprotein (HDL) cholesterol concentrations by the use of olive oil instead of unrefined carbohydrate type foods. This has been put to the test in NIDD by Garg *et al.*[51]. In this randomized cross-over study, each of two diets was given for 28 days. The high-monounsaturated-fat diet led to lower mean plasma glucose levels and reduced insulin requirements (subjects were placed on insulin for the duration of study), lower levels of plasma triglycerides and VLDL cholesterol, and higher levels of HDL cholesterol. Thus, from the point of view of glycaemic and lipid control, it would seem reasonable for diabetic patients to include olive oil as partial substitution for unrefined carbohydrate. It should be noted, however, that the dietary fibre contents were kept the same in the olive oil-carbohydrate comparisons and on information is provided in the study as to the sources of dietary fibre. Another consideration is that fat, in its own right, is more prone to lead to increase in body

fatness[52] and such an outcome may, in the long run, offset the advantage of olive oil seen in the study. Perhaps what is emerging is that the mediterranean diet, as one of several food cultures, may be conducive to improvement in overall diabetic control. Whether or not it will be possible to extrapolate from one monounsaturated-fat like olive oil to another such as peanut oil or avocado is not clear (these latter fats have a lower mono- to saturated ratio than does olive oil, in any case). The mechanism for the effects of olive oil is uncertain and could be attributable to components of olive oil other than monounsaturated fat.

Food intake and body fatness

Not only total body fat, but its distribution abdominally, increases the risk for diabetes[3] and total mortality[53,54]. Presumptively, control of the distribution of fatness is likely to be of value in the management of diabetes. There is increasing evidence that, long-term, regular physical activity is the preferred way of dealing with body fatness[55,56].

Sweeteners and sucrose in nutritional management

Whereas one of the most advocated dietary changes for diabetes was the avoidance of sucrose, recent acute[57,58] and long-term studies[59,60,61] in non-insulin-dependent and insulin-dependent diabetic patients have demonstrated that amounts of sucrose of the order of 30 – 40 g/day have no detectable effect on blood glucose or lipid control. It would therefore seem that diabetic patients can use small quantities of sucrose to sweeten their foods at meal time or in hot beverages. While not encouragement to use sucrose ad libitum, these findings may enable diabetic patients to adhere to the more important aspects of nutritional management, especially in those food cultures where the use of sucrose is so widespread.

Alcohol and nutritional management

Adverse effects of alcohol relevant to those with diabetes include pancreatic damage and hepatic cirrhosis as indicated above. Additionally, it has a high energy value of its own and may contribute to obesity. It also has potential to cause hypoglycaemia and to interact with oral hypoglycaemic agents. On the other hand, alcohol may have favourable affects through the facilitation of social activity and through increases in HDL cholesterol concentration. In those who have not been alcohol abusers in the past, it would seem reasonable to have modest amounts of alcohol, one to two standard drinks per day, preferably with food.

Food and health outcomes

Glycaemic and lipoprotein control in diabetes provide fairly ready feedback to patient and clinician about the ways in which food may be important. However, long-term morbidity and mortality outcomes are the most important considerations. It is possible that food intake may affect cardiovascular, renal, pharmacological and neurological complications in ways other than those currently regarded as important for blood glucose and lipoproteins. For example, there is limited work on dietary fatty acid composition and the development of retinopathy[62,63]. Again, there is currently interest in the possible value of protein restriction to delay decline in renal function[64,65,66,67,68]. It has been

suggested that protein intake be not more than 15% of energy intake.

It will probably be necessary to consider food intake in its entirety when predicting these outcomes from a nutritional point of view. If one takes cardiovascular disease, there are several pathways which may connect food intake to ischaemic heart disease. These include energy balance, plasma lipoproteins, fatty acid patterns in their own right and irrespective of lipoproteins (probably because of platelet function and cardiac membrane status and proneness to arrhythmia), platelet aggregation, coagulation profiles and hypertension. With respect to hypertension alone, there are at least several food considerations: sodium/potassium ratio, alcohol, vegetarian orientation and fatty acid pattern[67,69].

Because of the need to have more outcome data, short of major population studies, there has been considerable recent interest in the non-invasive monitoring of macrovascular disease in those with diabetes. For healthy subjects, Rel; *et al.*[70] have demonstrated that classical risk factors such as total cholesterol and HDL cholesterol are predictive of arterial wall characteristics like compliance. However, for NIDD patients, glycaemic status is the most important predictor of arterial compliance[71]. It seems likely that arterial compliance is an assessment which includes atherosclerosis as well as other arterial change such as glycation of arterial proteins. Plasma free fatty acid concentrations may be almost as important as glucose in the prediction of arterial compliance[71,72], but methodological accuracy may not allow free fatty acids to achieve the same predictive power as glucose.

Alternative indices of food intake-related health outcomes in diabetes

The glycaemic index has proven to be a valuable approach to describing the short-term effects of particular foods on blood glucose. Evidence is beginning to show that composite diets made up of food of low-glycaemic index may be useful for long-term prediction of blood glucose and lipoprotein control. It has yet to be seen, although expected, that such an approach would favourably influence morbidity and mortality rates.

Other nutritional considerations, like essential nutrient adequacy, may require alternative food indices. One of the most advocated dietary guidelines in industrialized countries is that a high degree of food variety be achieved. This recommendation is also made in the expectation that food variety would confer protection against chronic disease. This proposition has now been tested in respect of arterial wall characteristics by Wahlqvist *et al.*[73]. In this study, foods were discriminated from one another on the basis of their biological difference (e.g. ruminant meats, fish, wheat based, rice based, citrus fruits, stone fruits). Once a food had been used in an amount at least equivalent to an average serving size in the course of the week, it scored; used more often the score did not increase. Such a score of food variety, ranging from 4 or 5 to nearly 40, accounted for about 16% of the variance in arterial wall characteristics. Scores of this kind may allow food factors other than non-nutrients to be taken into account in predicting health outcome. However, the food variety score also significantly predicted fasting blood glucose and the area under a glucose tolerance curve in the same non-insulin-dependent diabetic patients.

Food education in diabetes

The emerging understanding of how food intake may favourably influence metabolic control and health outcome in diabetic patients now needs to be translated into action by way of education. It is well-known that knowledge does not necessarily lead to behavioural change.

In an effort to understand facilitators and inhibitors of nutritional change in those with diabetes, Kouris, Wahlqvist and Worsley studied factors associated with adherence and non-adherence to high unrefined carbohydrate, low fat diets in diabetic patients attending a Melbourne teaching hospital clinic[74]. In those who adhered, orientation towards health and health habits was greater and the need for motivation less: attitudes to diet were that it was worthwhile and attitudes to diabetes itself were that learning had been accomplished.

Adherers were more likely to recognize that they had achieved the use of target foods and they did not find food likes and dislikes a barrier to change.

Concepts and principles

The relevance in food education for diabetic patients which might be advanced include :

1. Respect for the patient's food culture.
2. Consideration of family, occupational and other personal needs.
3. An aim for overall health.
4. The positioning of food intake amongst other lifestyle variables, such as exercise, smoking and stress management.
5. The need to judge potential for change in glycaemic control through food in that particular individual (this may require an individual "experiment").
6. A distinction between short and longer-term effects of food as far as metabolic control is concerned.
7. Allowance for the use of insulin. For IDD patients, it should be possible to tailor insulin dosage around preferred food choice and meal pattern. For NIDD patients, food will need to be used to increase insulin sensitivity as much as possible.
8. Encouragement of self-monitoring of food intake and its relationship to outcomes. These outcomes will be not only the metabolic outcomes of glycaemic and lipoprotein control, but those of body composition and fat distribution (rather than weight alone), wellness and fitness, and, where possible, indices of macrovascular disease.

The **steps** towards the realization of the ultimate aims of low morbidity and optimal life expectancy could be :

1. Enunciate principles of food management of diabetes
2. Document current food intake and beliefs
3. Define the possibilities for favourable food change
4. Evaluate response(s)
5. Fine tune food intake at successive consultations

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