Nutrition Principles and Diabetes

A role for "lente carbohydrate"?

DAVID J.A. JENKINS, MD, PHD, DSC
ALEXANDRA L. JENKINS, BSC, RD, CDE

The current nutrition recommendations of the American Diabetes Association (ADA) represent a thoughtful synthesis of much current data. They depart from tradition by not advocating specific figures for total fat and carbohydrate intake. Rather, since many issues are still topics of scientific debate, they endorse the principle of individualization and set guidelines accordingly. One topic that may be worthy of further debate is the principle of "spreading the nutrient load," or lengthening the absorption time. This principle covers the effects of altered meal frequency, viscous dietary fibers, low–glycemic index foods, and inhibitors of carbohydrate absorption. In its simplest form it is illustrated by studies of altered meal frequency ("nibbling versus gorging"). Reducing the size and increasing the frequency of meals has been shown acutely to result in lower mean blood glucose and insulin levels over the day in type II diabetes and to result in reduced 24-h urinary C-peptide losses. In the longer term in nondiabetic subjects, total and low-density lipoprotein cholesterol levels are reduced, together with fasting apolipoprotein B and serum uric acid levels, as additional risk factors for coronary heart disease. These and other physiological effects make slowing carbohydrate absorption ("lente carbohydrate") a potentially useful therapeutic modality. However, of the possible ways of slowing absorption, only alteration in meal frequency was of general interest in the current ADA nutrition recommendations. Nevertheless, the effects of slowing carbohydrate absorption by various means may have beneficial metabolic effects in diabetes and may support the use of ethnic foods in diets compatible with further modifications identified more favorably in the current nutrition recommendations (e.g., increased use of monounsaturated fat).

The current "Nutrition Recommendations and Principles for People with Diabetes Mellitus" of the American Diabetes Association (ADA) represent a departure from traditional recommendations in stressing individualization of diet based on the patient's lifestyle and the results of clinical monitoring (1). Specific goals for the percentage of calories consumed as carbohydrate or total fat are avoided, and instead "Dietary Guidelines for Americans" (2) and the "Food Guide Pyramid" (3) are cited as a general basis for healthy eating (1). If serum cholesterol levels are raised, then the National Cholesterol Education Program (NCEP) guidelines are to be followed.

This approach has the advantage that it acknowledges the shifting sands of science and encourages the patient and his physician to define together, through trial and error, an individual path within the confines of a healthy diet. On the other hand, to maximize the effectiveness of the advice, it might have been useful to spell out under several headings, depending on the dominant clinical problem, the possible treatment options in a stepwise progression, starting with those with the greatest chance of success in a particular situation and concluding with those that might be considered long shots. In addition, even when relying on a standard as seemingly basic to general health as the "Food Guide Pyramid," it may be worthwhile to consider its possible deficiencies (4).

Despite these comments, the new guidelines and the technical review on which they are based are a thoughtful synthesis of much of the scientific literature relevant to diabetes and associated disorders, including cardiovascular and renal disease (5). Even so, as in all such undertakings, the published review can only represent a small fraction of the work, debate, and discussion involved in formulating the guidelines. Particularly welcome, therefore, is the continuation of the approach started under Dr. Vinic's chairmanship (5a) of extensive explanatory papers, or paper in this case (5), citing the data on which the guidelines are based and concluding with the research questions posed (5).

RANKING OPTIONS— Our concern is that some of the suggestions may

From the Clinical Nutrition and Risk Factor Modification Center, St. Michael's Hospital, and the Department of Nutritional Sciences, Faculty of Medicine, University of Toronto, Toronto, Ontario.

Address correspondence and reprint requests to David J.A. Jenkins, Clinical Nutrition and Risk Factor Modification Center, St. Michael's Hospital, 30 Bond St., Toronto, Ontario M5B 1W8, Canada.

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ADA, American Diabetes Association; HDL, high-density lipoprotein; LDL, low-density lipoprotein; NCEP, National Cholesterol Education Program.

have been too cautious (5). We applaud the latitude provided by the current guidelines to allow testing on an individual basis until clear scientific data favoring specific treatment options emerge. However, we feel that it would be useful to have all potential treatment options discussed and ranked. Separate lists would be constructed for those with poor glycemic control, the overweight, especially those with high triglyceride and low high-density lipoprotein (HDL) levels, and those with raised low-density lipoprotein (LDL) cholesterol levels (partly covered by NCEP guidelines for individuals without diabetes). This approach would guide individualization while still allowing some less favored options to be tested rather than dismissed. This concern in part reflects a personal bias toward maximizing the use of carbohydrate foods by identifying possible options for their use, in spite of a lack of general scientific consensus. Our focus is on a general principle that may be helpful in the management of both diabetes and hyperlipidemia. The principle is that of prolonging the time of nutrient absorption from the gut. Some factors of interest contributing to the prolongation of absorption are shown in Table 1. The first three are discussed in the guidelines (1,5). All of them can be used to support current NCEP guidelines and may have specific glycemic advantages. We have attempted to draw these strategies together in the context of the current nutritional guidelines.

Table 1—*Factors contributing to "spreading the nutrient load"*

Increased food frequency ("nibbling versus gorging")
Viscous soluble fibers (guar, pectin, β-glucan, psyllium, etc.)
Low–glycemic index foods (dried legumes, barley, pasta)
Enzyme inhibitors of absorption (e.g., glucosidase inhibitors)

FOOD FREQUENCY, FIBER, AND GLYCEMIC INDEX IN CURRENT RECOMMENDATIONS—

Spreading nutrient intake throughout the day was acknowledged as possibly beneficial in some individuals (5). Soluble fiber was seen as having a marginal effect in reducing blood total and LDL cholesterol (5). It was stated that the amount required was considered difficult to consume by food alone, which is true for a number of reasons. The references justifying this statement were all to guar gum supplements (10–12). Guar and other viscous fibers have proved difficult, although not impossible, to incorporate into palatable food. At the same time, it was concluded that the effects of dietary fibers on glycemic control are probably insignificant and that supplemental concentrated fiber preparations could not be recommended (5).

Knowledge of the glycemic index of individual foods was not considered to be useful for individual meal planning, and concern was expressed that recommending foods at the low end of the scale may severely limit food choices (5).

No mention was made of lessons learned with enzyme inhibitors that slow absorption, such as acarbose, which although not in use in North America, are available and used in Europe. Extensive studies have been carried out on these inhibitors for the treatment of diabetes in both Europe and North America over the last 15 years (13–16).

EVEN-HANDED CAUTION—

It is easy for critics of the current recommendations to focus on areas of special interest to themselves, especially in a document that is comprehensive in scope. It might also be maintained that caution should prevail over enthusiasm for treatment options where clear success in application has not been demonstrated. In this respect, the committee members have been even handed (5).

They are cautious not to advise less than the recommended daily allowance for protein to prevent or delay the development of diabetic renal disease. They identify the dilemma over high carbohydrate versus higher fat, especially monounsaturated fat (17–22), indicating possible benefits of monounsaturated fat (18), but conclude with a reference to an 18-month study in which the final nutrient intake was the same, regardless of the initial advice (23). This caution may have been enhanced by prior knowledge of the results of what is likely to be the definitive paper on the effects of monounsaturated fat versus carbohydrate in type II diabetes, published subsequent to the ADA guidelines, and co-authored by some of the ADA committee members (23a). This paper demonstrated increases in very-low-density lipoprotein cholesterol and triglyceride on the high-carbohydrate diet, together with increased levels of day-long insulin and glucose. However, the anticipated advantages of monounsaturated fat in producing a relative increase in the ratio of total to HDL cholesterol or in significantly reducing the level of HbA_{1c} were not demonstrated. This was despite the use of a crossover design combined with metabolic control and the use of a large number of subjects (43) over a relatively long period of time (8 or 14 weeks) (23a).

Sucrose was accepted within the diabetic meal plan, but fructose, despite its glycemic advantage (24–26a), was considered to be no better than other nutritive sweeteners because of concern over its potential ability to raise LDL cholesterol (26–28). Nevertheless, fructose and sucrose did not appear to differ in their effects on LDL cholesterol (29,29a).

IN SUPPORT OF DIETARY FIBER AND THE GLYCEMIC INDEX CLASSIFICATION

Fiber

Because of our bias, we are less cautious in our assessment of the possible use of dietary fiber and the glycemic index as potential ways of slowing nutrient uptake from the gut. It is those viscous fibers that reduce the rate of absorption that lower serum cholesterol levels. Our interpretation of the literature is that 5–15 g of viscous fiber (e.g., guar, pectin, psyllium, or β-glucan from oats and barley) or fiber from dried legumes will reduce serum cholesterol levels by ~5% or more (30–31). The lipid lowering is accompanied by an increase in fecal bile acid excretion (31–34). The bile acid losses relate to the reduction in LDL cholesterol and apolipoprotein B, possibly explaining 10–20% of the effect (35). Increases in fiber have been achieved using both foods and supplements. The former are likely to be more palatable, but for many individuals, the smaller volume and convenience of supplements are of greater importance.

The fiber sources that reduce serum cholesterol levels are the same viscous fibers that have an effect on glucose tolerance (35a-37c). Although at present supplements may not be recommended to improve glycemic control on the basis of the failure of long term crossover trials of guar and beet fiber to demonstrate an improvement in glycosylated hemoglobin (38), the same supplements or supplemented foods may still be useful in improving serum cholesterol levels and possibly fibrinolysis (38a). Furthermore, despite a lack of crossover studies, there are recent reports suggesting that guar supplements reduce blood lipids, glycosylated hemoglobin (38b,38c), and serum fructosamine (38b) in type I (38b) and type II diabetes (38c).

Glycemic index

The differing effect of various carbohydrate foods in raising the blood glucose postprandially has long been recognized (38d,38e). A glycemic index classification was undertaken to provide an indication of the rates at which different starchy foods are digested (39–40). It was hoped that selection of foods with lower glycemic indexes would contribute to prolonging the absorption of nutrients, so improving the glycemic profile (41–42) and reducing fasting lipids (43).

However, a number of acute (up to 1 day) mixed-meal studies during the mid-to-late 1980s suggested that a glycemic index classification of foods had no clinical utility (44–46). The current assessment of the Nutrition Committee is based on these findings (5). Nevertheless, since the late 1980s, there have been reports documenting improved glycemic control in both type I and II diabetes judged by serum fructosamine and HbA_{1c} levels in studies of 2 weeks' to 2 months' duration (47–52). Where the effects of high– and low–glycemic index diets have been compared, changes in blood measurements have been noted despite often relatively small differences in glycemic index between test and control diets. Furthermore, some studies also noted reductions in serum lipids (47–51a). Many high-fiber foods that lower LDL cholesterol also have low glycemic indexes (e.g., barley, beans, etc.). Looked at in another way, exploration of low–glycemic index foods might be used to expand rather than limit the carbohydrate food choices of people with diabetes.

Enzyme inhibitors

Some mention of the pharmacological concept of slowing absorption and the lessons learned would also have been helpful despite the fact that enzyme inhibitors have not been released for clinical use in North America. Alpha glucosidase inhibitors, such as acarbose, which reduce the rate of absorption of starch, sucrose, and to a lesser extent maltose (53), have recently been shown in a large multicenter trial to result in a significant reduction in HbA_{1c} in type II diabetes (16). Findings of this nature provide additional encouragement that spreading the nutrient load, in addition to altering the amount and nature of the nutrients, may one day have a role in the management of diabetes.

Food frequency

In the absence of general agreement on the value of viscous fibers, low–glycemic index foods, or enzyme inhibitors, what support is there for the underlying concept of spreading the nutrient load? In this respect, the ultimate model is perhaps meal frequency, where the nutrients remain the same but the rate of delivery is changed.

THE METABOLIC POTENTIAL OF SPREADING THE NUTRIENT LOAD

— Over a quarter of a century ago, Fabry and Tepperman (54) noted that individuals who ate more meals during the day, thus effectively prolonging absorption time, had a reduced rate of coronary heart disease and a lesser incidence of diabetes and obesity. The reasons were not clear, but the observation has sparked interest in this aspect of nutrition since that time (54–65). Indeed, for over three centuries the phenomenon of food frequency has been considered of importance to human health, starting with the metabolic studies of Sanctorius in the early 17th century and continuing more recently with the studies of Ellis in the 1930s. Ellis demonstrated a reduction in insulin requirements in patients with diabetes when glucose and insulin were administered in small frequent doses (66). Since then, a number of studies have noted various metabolic benefits that were ascribed to increased meal frequency (the nibbling versus gorging phenomenon) (Table 2).

Earlier studies noted reductions in total cholesterol levels with increased meal frequency (55,57,58). Later studies demonstrated that the reduction was in LDL cholesterol when eating 3 meals was compared with eating as few as 6 or as many as 17 meals daily for periods of 2–8 weeks (59–61a). In an extreme model of slowing absorption, and it must be stressed that this must be seen as simply a model, where 17 meals daily were used, lower levels of apolipoprotein B were also demonstrated (59). Population studies confirmed that total cholesterol levels were lower in those who ate more meals daily (64). Stable isotope studies indicated that cholesterol synthesis was reduced at greater meal frequencies (62). Studies using urinary mevalonic acid excretion as a water soluble marker of cho-

Table 2—*Possible effects of prolonging absorption time of carbohydrate*

Flatter postprandial glucose profile (60, 62, 65, 66, 69)
Lower mean insulin levels postprandially and over the day (60, 62, 65, 66, 69)
Reduced gastric inhibitory polypeptide response (60, 65, 69)
Reduced 24-h urinary C-peptide output (59, 60)
Prolonged suppression of plasma free fatty acids (69)
Reduced urinary catecholamine output (69)
Lower fasting and postprandial serum total and LDL cholesterol levels (55, 58, 59, 61, 67)
Reduced hepatic cholesterol synthesis (62)
Lower serum apolipoprotein B levels (59)
Lower serum uric acid levels (67)
Increased urinary uric acid excretion (67)

lesterol synthesis indicated that the change in cholesterol levels also related to the change in urinary mevalonic acid output (67). The reduction in cholesterol synthesis was attributed to the lower insulin levels observed, since insulin is known to stimulate hydroxymethylglutaryl coenzyme A (HMGCoA) reductase activity, a rate limiting enzyme in cholesterol synthesis (68). A further possible reason for the reduction in serum cholesterol on a nibbling diet is that bile acid losses would be increased because of more frequent bile acid cycling through the gut. These losses of the cholesterol molecule as bile acids would further enhance the cholesterol-lowering effect of increased meal frequency.

Recent studies in type II diabetes have demonstrated lower glucose and insulin levels during the day when meal frequency was increased (60,65). In nondiabetic subjects, the major effect of reducing the absorption rate (by sipping glucose over 3 h versus taking the same amount of glucose as a bolus within 5 min) was to reduce insulin secretion (69). In addition, insulin suppression of free fatty acids and branched-chain amino acid levels was prolonged and no post-glucose challenge counterregulatory response was observed.

Finally, serum uric acid levels were reduced and urinary uric acid excretion was increased with increased food frequency (67). As with the reduction in serum cholesterol levels, the effect of lower insulin levels was invoked as an explanation (67). In this situation, the effect of insulin was suggested to promote renal reabsorption of uric acid, as demonstrated in the context of hyperinsulinemic states (70).

Other physiological effects of food frequency have been explored that are relevant to diabetes. The possible effects of food frequency in limiting obesity through alteration in adipose tissue enzyme levels has been explored (56). Acute studies of the effects of meal frequency in humans showed a reduced thermogenic response with increased meal frequency and thus did not provide a reason for the metabolic benefits seen with nibbling (63). However, assessment of satiety in acute studies suggested that fluctuations in satiety were blunted over the day (60), but the all-important chronic studies have yet to be undertaken. Until then, there remains the concern that snacking may increase the body weight of those who most need to lose weight. Nevertheless, irrespective of whether increased meal frequency as such is broadly applicable in practice, the demonstration that it can improve certain aspects of lipid and carbohydrate metabolism makes it a valuable model for other methods of spreading the nutrient load.

AVAILABILITY OF HIGH-FIBER AND LOW-GLYCEMIC INDEX FOODS AS A BARRIER TO SUCCESSFUL USE

— The issue of food availability is important. It has been commented that it is predominantly the viscous fiber sources that have been shown to have effects on glucose and lipid metabolism (5,38), and these are relatively few in number. In addition, the number of foods in the Western diet that are truly low glycemic index are also few and not commonly eaten, hence the concern that low–glycemic index diets would be restrictive (5).

Wheat products are major fiber sources in Western diets, and wheat fiber is largely without effect on blood glucose and serum lipids (35a,37). Consequently, it is not surprising that prospective studies have found no association between fiber consumption and freedom from subsequent development of diabetes (72). Interestingly, associations were noted between increased carrot and cabbage consumption and a reduction in subsequent development of diabetes (72). Only 10% of the fiber in wholemeal bread is soluble, compared with ~50 and ~30% in carrot and cabbage respectively (72).

In other cultures, low–glycemic

Table 3—*Glycemic index of staple foods from different cultures*

Food	Average glycemic index	Culture	Reference
White bread rolls	100	North American, European	—
Pumpernickel bread	70–90	North European	76
Pasta	50–70	Mediterranean	39,77,78
Cracked wheat (tabouli)	60–70	Mediterranean, Middle Eastern	76
Beans, lentils, dried peas	40–70	Southern U.S., Latin American, Middle Eastern, Indian, Oriental	39,77–79
Parboiled long-grain rice	70	Asian, North African	78

Glycemic index is rounded to the nearest 10%.

index foods are more common (Table 3), and some diets even contain significant amounts of viscous fibers.

LOSS OF LOW-GLYCEMIC INDEX FOODS FROM THE MODERN DIET? — Finally, it may also be asked whether there has actually been a change in the rate at which we absorb our food, as exemplified by a change in the mean glycemic index of our diets, and whether the current value is higher than that of our ancestors (73). Many traditional staple foods around the world have low glycemic indexes (Table 3) (39,73,76–78). Studies of Australian Aborigines suggest that their original starchy foods were low glycemic index (74). In other high-risk groups for diabetes, such as the Pima Indians, it appears that low–glycemic index starchy foods such as beans and acorns were also featured as staples in their original diets (74a). These issues raise the question of the possible value of preserving certain traditional dietary habits of specific cultures, especially for those whose genetic make-up renders them more vulnerable to diabetes (74b). Knowledge of this kind may provide encouragement for, rather than simply sensitivity to, ethnic and cultural food issues. Furthermore, traditional low–glycemic index diets would be compatible with other dietary strategies such as the increased use of monounsaturated fats (e.g., olive oil added to pasta and bean dishes in the Mediterranean diet).

CONCLUSIONS — In the current ADA recommendations, in addition to the identification of useful and possibly not-so-useful dietary strategies, it would have been helpful to have a clearer ranking of these strategies in terms of their effectiveness and the situations in which they might be most appropriate. This approach would allow choice and provide guidance to individuals who may wish to try treatment options in those areas where there is still doubt. Additionally, such a move might have provided encouragement to the food industry to maintain or develop products that facilitate nutritional change. These developments would also be of advantage to the population in general. In the meantime, there is still reason to hope that viscous fibers and low–glycemic index foods may have clinical utility by making a worthwhile impact through LDL cholesterol reduction and possibly long-term glycemic control. The value of combining these with other strategies, such as increased meal frequency or use of digestive enzyme inhibitors, remains to be determined. Possibly the bottom line, in contemporary dietary advice, is that we are increasingly turning to plant-based diets with increased consumption of green leafy vegetables, unsaturated (especially monounsaturated) vegetable oils, and high-fiber starchy foods (cereals, legumes, etc.) (4,75). This advice is for the general public, and it is likely to apply equally to those with diabetes.

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