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REVIEW

Diets for body weight control and health: the potential of changing the macronutrient composition

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At the beginning of the last century obesity and type 2 diabetes were treated quite successfully using low-carbohydrate diets. Following the discovery of insulin, the carbohydrate content of the diabetic diet became more liberal, as glycaemia and glycosuria could be controlled, more or less well, with hypoglycaemic medication and insulin treatment. Later, saturated fats and high-plasma cholesterol concentrations were implicated in cardiovascular disease and since then high-carbohydrate diets have become synonymous with 'health' and have been conventional nutrition doctrine for the past 40 years. In spite of this, the prevalence of some non-communicable metabolic diseases have increased to epidemic proportions and have led an increasing number of researchers in the fields of medicine and nutrition to challenge the validity of present-day dietary guidelines. There is increasing evidence that diets with a lower, or even very-low, carbohydrate content can help overweight and obese individuals to lose and maintain lost weight, diabetics to control blood glucose with more ease and prevent the development of diabetic complications, while at the same time improving blood lipid profiles and biomarkers of cardiovascular risk. The present review considers the evolution of our diet and questions whether high-carbohydrate diets are indeed synonymous with health.

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INTRODUCTION

At the beginning of the 19th century, the British economist Thomas Malthus[1] developed the theory that human population growth would overwhelm and be controlled by the food supply; shrinking in times of war and famine and expanding in times of plenty. However, for many countries of the developed world that have experienced, and taken advantage of, the industrial, agricultural and technological revolutions; social, political and economic stability has led to food security providing a large and readily available food supply. This has not only resulted in population growth, as predicted by Malthus, but population girth and increased mortality and morbidities from non-communicable diseases, the antithesis of Malthusianism, where a plentiful food supply is associated with population decline.

Interestingly, Darwin used Malthusian theory to develop his concept of natural selection,[1] and food supply has played a role in our own evolution since Palaeolithic times.[2] It is generally accepted that Homo sapiens evolved as hunter-gatherers, and although there is debate about the macronutrient composition of our ancestral diet[3–7] with carbohydrates contributing 3–50%,[4] depending upon whether our ancestors were primarily hunters or gatherers, the distribution of macronutrient energy was of the order of 30% protein, 35% fat and 35% carbohydrate[4,5] supplied by animal flesh, tuberous vegetables, fruits and nuts.[7] With the development of agrarian societies during the Neolithic period, and especially the advances in farming practices and technology over the past 200 years, the quantity and quality of our diet and our lifestyle has changed quite dramatically. While these changes have brought many advantages, they have also been accompanied by an increase in chronic non-infectious diseases, such as heart disease, cancer, stroke, diabetes, obesity and related morbidities that are the leading cause of death in present-day society.

DIETARY RECOMMENDATIONS

At the turn of the last century, the American diet was composed of ~35% energy from fat, increasing to ~40% in the 1950s and 1960s and was composed of ~16% saturated, 17% monounsaturated and 4% polyunsaturated fatty acids,[8] and it was about this time that Keys[9] popularized the relationship between saturated fats, blood cholesterol and heart disease. Although, he demonstrated that the proportion of energy provided by dietary fat could explain 94% mortality from coronary heart disease using results from the six countries study, Yerushalmy and Hilleboe[10] drew attention to the fact that when data from 21 countries were included, this relationship was reduced to 1%. Even though Keys[9] admitted that large amounts of dietary cholesterol had very little effect on its blood concentration[11] and there was little evidence to support reducing the fat content of the American diet,[12] he and disciples of the 'diet–heart hypothesis' were able to convince the American Heart Association and other health organizations to decrease the fat content of the diet,[13] which resulted in a corresponding increase in carbohydrate energy and the foundation of present-day dietary guidelines. Despite reports that there was a decline in mortality from coronary heart and cardiovascular diseases as a result of the recommended improvements in diet and exercise habits,[14,15] and incidentally the introduction of antihypertensive medication and improved therapies, they have been confounded by the increasing prevalence of obesity and diabetes that has occurred since then and for which heart disease is a related morbidity.

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At the present time, high-carbohydrate, low-fat diets are recommended as 'healthy' for the population in general[16] as well as for individuals susceptible to heart disease,[15] cancer,[17] hypertension[15,18] and diabetes.[19] However, in spite of these recommendations, there is considerable evidence that high-carbohydrate, low-fat diets promote the insulin resistance syndrome[20–23] and that they are not favourable for patients with mild-to-moderately severe type 2 diabetes.[24] In some individuals, high-carbohydrate diets promote the conversion of less atherogenic large low-density lipoproteins (LDL) into the more atherogenic small, dense LDL[25] and fructose, once considered the ideal sweetener for diabetics, has now been shown to predict smaller LDL particle size in schoolchildren.[26] These arguments, together with more recent evidence that low-carbohydrate diets have health benefits for weight management,[27–30] diabetes[31,32] and cardiovascular disease[28,33–36] have led an increasing number of scientists to challenge present-day dietary guidelines,[37–40] whereas others question the relationship between dietary saturated fat and increased risk of cardiovascular disease[41,42] and the validity of reducing saturated fats to minimal levels.[43]

DIETARY TREATMENT OF DIABETES

A number of large cohort, long-term clinical trials have documented that tight glycaemic control has benefits not only in preventing the onset and progression of type 2 diabetes,[44–46] but also in preventing or delaying the development of diabetic complications, such as retinopathy, nephropathy, neuropathy, foot ulcers and cardiovascular disease.[44–48] In consequence, effective treatment of hyperglycaemia is the priority of diabetes associations worldwide[49] to maintain blood glucose concentrations as near to normal as possible. Other studies have implicated high postprandial glucose concentrations as a risk factor for cardiovascular disease in both diabetic and non-diabetic individuals[50–53] as well as in the development of microvascular complications of diabetes[50,51,53] and propose that targeting both chronic and acute glucose fluctuations is necessary[51] to prevent their onset or progression. In spite of this, diabetic patients are still advised to consume a high-carbohydrate diet and to control glycaemia with hypoglycaemic agents and/or insulin, which even specialists in the field agree are associated with adverse side effects, such as reactive hypoglycaemia and weight gain.[54,55] It is perhaps surprising that when saturated fats were only weakly associated with cardiovascular disease in the 1950s, the recommendations were to decrease saturated fats and cholesterol in the diet. However, when studies provide irrefutable evidence that hyperglycaemia, in large part the result of consuming dietary carbohydrates, is associated with increased risk of cardiovascular diseases in apparently healthy individuals[52] and is responsible for the progression of type 2 diabetes and the debilitating complications of both type 1 and type 2 diabetes,[50,51,53] the recommendations are to consume a high-carbohydrate diet.

Before the discovery of insulin low-carbohydrate, low-energy diets were the treatment of choice for endocrinologists, such as Allen, Adlersberg,[56] Joslin[57] and Newburgh, however, 25 years after the use of insulin treatment Adlersberg[56] lamented that its use had led to neglect of the dietary treatment of diabetes and emphasized that many mild and moderately severe cases of type 2 diabetes could be satisfactorily maintained without insulin by the proper application of 'dietotherapy'. Indeed Joslin[57] writing about the same time commented 'insulin is so good that doctors and patients take advantage of it, disregarding diet and exercise'.

When describing the diet used by his patients at the George F Baker Clinic in 1941, Joslin[57] indicated that the average carbohydrate intake for all patients and all ages was 156 g or 624 kcal/day, corresponding to ~30–40% of their daily energy intake, and commented 'with the carbohydrate in the diet as high as 150 g, the chances of a diabetic not being able to obtain enough calories in the form of protein and fat seem slight'.[57] However, in the 70 years since this statement was made, the carbohydrate component of the diabetic diet has increased from ~30% to as much as 65%[58,59] of daily energy requirements. Is this due to improvements in medical nutrition and pharmaceutical therapy for diabetics or is it as Joslin[57] feared that 'insulin is so good that it covers up a multitude of therapeutic sins.'?

OPTIMAL DIET

Most scientists agree that poor diet and physical inactivity are the major factors contributing not only to overweight and obesity but also to the increased prevalence of today's metabolic diseases. In consequence, it should be possible to prevent or delay their onset by following an appropriate diet and increasing physical activity, rather than treating the consequences of an inappropriate diet by pharmaceutical means. The latest dietary guidelines for Americans[16] propose a healthy eating pattern composed of nutrient rather than energy-dense foods with a macronutrient composition within the acceptable distribution ranges recommended by the Institute of Medicine.[60] However, the Acceptable Macronutrient Distribution Ranges are quite large, especially for carbohydrate (45–65%) and protein (10–35%) and although it is indicated that reducing energy intake is more important for body weight control than the proportion of macronutrients in the diet; if changing the macronutrient composition of the diet can help some individuals to reduce energy intake, decrease body weight and improve biomarkers of cardiovascular disease, it is certainly worth trying.

Over the last decade, a number of clinical trials have demonstrated that reducing the carbohydrate content of the diet not only improves weight loss but also improves biomarkers associated with cardiovascular disease[27–29] and often results in reduced medication for type 2 diabetics,[29] independent of weight loss. Such observations are not new and have been demonstrated in obese type 2 diabetics consuming a Protein Sparing Modified Fast.[61] More importantly, low-carbohydrate diets have often been consumed *ad libitum* and compared with reduced energy diets, indicating that by consciously avoiding or reducing added sugars, refined grains and their food products, an individual is able to unconsciously reduce his, or her, spontaneous energy intake. Whether this is due to a diet slightly higher in protein quantity and composition or that it is more structured and restrictive has not been determined. However, even when such diets are consumed to maintain body weight, improvements in disease-associated biomarkers have been observed.[62,63]

With the exception of a few food groups, such as dairy and grains, which have become ubiquitous nutrient sources since the agricultural revolution, dietary recommendations appear to be evolving in the direction of diets consumed by our Palaeolithic ancestors, for whom some believe our present genome is most adapted.[64] Indeed, the latest Dietary Guidelines for Americans propose the DASH (Dietary Approaches to Stop Hypertension) diet as a healthy diet. Although this diet only provides 15% daily energy intake from protein, with the remainder composed of 58% carbohydrate and 27% fat, results from the OmniHeart trial,[63] in which the subjects maintained their body weight constant for periods of 6 weeks, indicate that further reductions in cardiovascular risk (lower blood pressure and improved blood lipid profiles) can be obtained when either protein or unsaturated fats (predominantly monounsaturated fatty acids) replace and reduce the carbohydrate content by 10% (Figure 1)

Although it is not possible to determine if the observed improvements were due to the decrease in carbohydrates alone, the increase in protein or unsaturated fats *per se* or their respective compositional changes, it would have been interesting to see whether a combination of these two diets (Figure 2

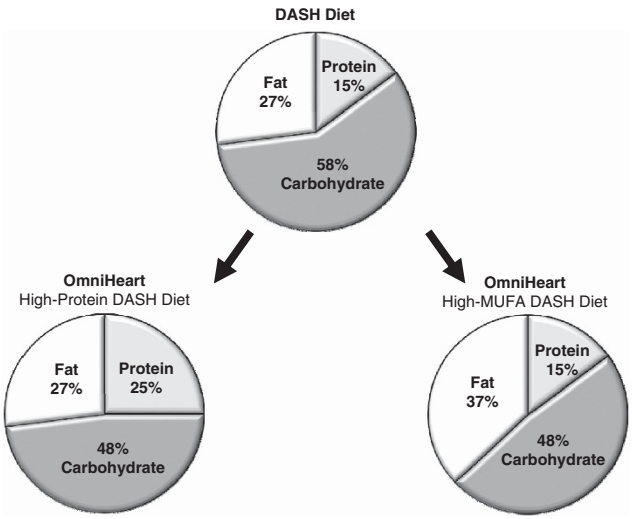

Figure 1. Modification of the DASH (Dietary Approaches to Stop Hypertension) diet used in the OmniHeart trial.[63]

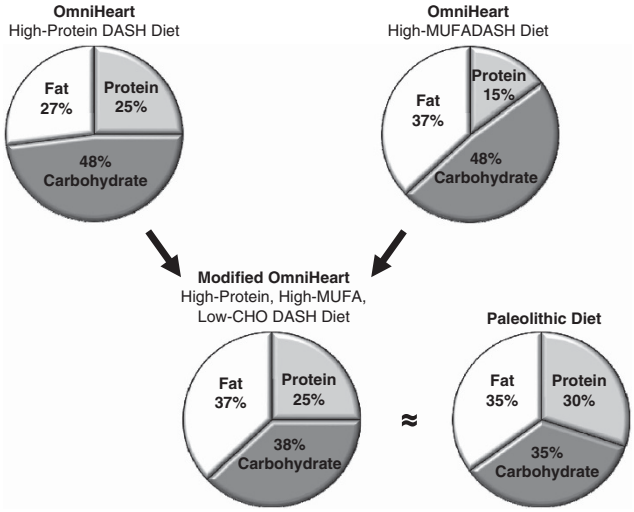

Figure 2. Combination of the high-protein and high-monounsaturated fatty acids (MUFA) components of the OmniHeart diets would have reduced the carbohydrate composition to 38%. Would further improvements in cardiovascular risk factors have been observed? DASH, Dietary Approaches to Stop Hypertension.

Modified OmniHeart) might have further improved cardiovascular risk factors, as the carbohydrate content would have been reduced further and the macronutrient composition is quite similar to that of the Palaeolithic diet. In the OmiHeart study, the carbohydrate content of the diet was reduced from 58% to 48%, however, others have demonstrated that if the carbohydrate content of the diet is reduced even further, as in very-low carbohydrate diets,[65,66] the quality of dietary fat, saturated or unsaturated, does not need to be controlled to improve biomarkers of cardiovascular disease and decrease those of inflammation.

Reducing the carbohydrate content of the diet as in very-low carbohydrate diets, referred to as ketogenic diets, is not only of interest for controlling obesity and diabetes but neurological diseases as well. They have proved effective for decreasing epileptic seizures and more recently they have been proposed as therapy for a variety of neurological disorders that include Alzheimer's and Parkinson's disease[67] as well as narcolepsy.[68] Although the mechanisms by which ketogenic diets exert their effects are unclear, they do appear to normalize aberrant energy metabolism and have neuroprotective properties.[67]

PROTEIN INTAKE, HOW HIGH SHOULD IT BE?

A recent analysis of the National Health and Nutrition Examination Survey data to determine trends in macronutrient composition of the diet, energy intake and body weight from 1971 to 2006, found that the increased prevalence of obesity in 2006 was associated with increases in energy and carbohydrate intakes and decreases in the proportions of fat and protein in the diet.[69] It was further observed that a 1% increase in protein intake, replacing either carbohydrate or fat, decreases energy intake by 32 and 51 kcal, respectively. The authors conclude that while efforts should be focused on decreasing energy intake, this may be facilitated by increasing the protein composition of the diet.

A substantial decrease in the quantity of refined carbohydrates in the diet will be accompanied by increases in the composition of protein and fat, but this does not necessarily mean that the quantities of protein and fat in the diet will or should increase. Proteins are more satiating than carbohydrates[70] and a number of studies have demonstrated spontaneous decreases in energy intake as the proportion of protein in the diet increases, or that subjects feel more satiated on higher protein diets. However, when energy intake is restricted, it is possible that protein requirements are greater than present-day dietary recommendations of 0.8–1 g/kg/day, to maintain nitrogen balance and ensure that lean body mass is not compromised during weight loss.[71] One argument against increasing the protein content of the diet, especially with age, was the belief that due to its effect on acid/base balance and increased calcium excretion it exacerbates osteoporosis, but it is now understood that osteopenia and sarcopenia observed with ageing are interrelated and that optimal protein intakes to prevent bone and muscle degeneration are probably greater than current recommended dietary allowances[72] and that higher protein diets are associated with greater bone mass and fewer fractures when calcium intake is sufficient. The acid-producing effects of high-protein intakes can be mitigated by the alkalinizing effects of fruits and vegetables or, in the case of very-low carbohydrate diets, potassium bicarbonate supplementation, which has been shown to reduce urinary nitrogen excretion and increase fractional calcium absorption.[73]

DIFFERENT PROTEINS DIFFERENT EFFECTS

Not only is an increase in the amount or proportion of dietary proteins thought to improve weight loss, heart health and prevent or retard the development of type 2 diabetes[74] but protein quality also seems to offer health benefits.

Whey proteins are digested and absorbed more rapidly than casein, which influences postprandial plasma amino-acid profiles and increases muscle protein synthesis more than that of casein in older men.[75] As a consequence, whey protein, together with resistance training, has been proposed to prevent age-related sarcopenia.[75,76] However, as casein has also been shown to increase muscle protein synthesis and whole-body protein retention in elderly men when administered during sleep,[77] nutritional strategies combining rapidly digested whey protein supplementation during the day with a slowly digested casein meal immediately before sleep may be more effective in preventing sarcopenia than one based upon whey protein alone.

Whey protein supplementation at 60 g/day for 4 weeks, in obese non-diabetic women consuming their habitual diet was also shown to decrease liver lipids, fasting triglycerides and total cholesterol,[78] however, whether these effects were specifically due

to whey protein or the increased protein content of the diet cannot be determined.

Mikkelsen *et al.*[79] observed that 24-h energy expenditure (24-h EE) increased after 4 days of replacing dietary carbohydrate isocalorically with either 17% animal or vegetable proteins but that animal proteins stimulated 24-h EE slightly but significantly more than vegetable proteins; and we have made similar observations using different protein sources, in which an isocaloric whey protein test meal increased EE more than those composed of casein or soy.[80] Interestingly, the glucose responses to these test meals were lower than that of a meal containing the same amount of glucose alone. The lower glucose response after whey could be explained by a larger insulin response; however, the insulin responses following casein and soy were not significantly different from that after consuming the glucose meal alone. These results, together with those of other proteins, suggest that specific proteins can be incorporated into the diet to provide distinct and desired attributes tailored to take into account the health and metabolic conditions of the individual.

CONCLUSION

There is little doubt that much of the present pandemic of metabolic diseases is due to a combination of inappropriate diet(s) and lack of physical activity. Consequently, it should be possible to prevent or delay their development by appropriate 'dietotherapy' with little, or no, pharmaceutical intervention. In 2005, The Joslin Diabetes Centre issued 'new' dietary guidelines, reminiscent of those used by its founder at the George F Baker Clinic 70 years ago, in which they recommend 40% energy from carbohydrates, 20–30% from proteins, 30–35% from fats and containing at least 20–35 g of fibre. When incorporated into their 12-week 'Why Wait' diet and exercise programme,[55] patients lost weight, composed of fat rather than lean mass, that was maintained for 1 year and although they did not increase their protein intake significantly, they were able to reduce or completely stop taking their diabetes medication. Dietary recommendations are reviewed at regular intervals and are updated according to evidence-based data published in the literature. With increasing evidence indicating the advantages of low-carbohydrate, higher protein diets having health benefits and proof-of-principle that the Joslin Centre's 'Why Wait' programme can prevent and even reverse the progression of type 2 diabetes, is it not, conceivable, that such diets are more appropriate for optimal human health than the carbohydrate-rich diets that continue to be recommended?

CONFLICT OF INTEREST

KJA is an employee of Nestec Ltd., a subsidiary of Nestlé Ltd, which provides professional assistance, research and consulting services for food, dietary, dietetic and pharmaceutical products of interest to Nestlé Ltd. There is no conflict of interest concerning opinions presented in this review.

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