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Dietary, Lifestyle Factors and Type 2 Diabetes

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Introduction

Type 2 diabetes mellitus is characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. The chronic hyperglycemia of diabetes is associated with long-term damage, dysfunction, and failure of various organs, especially the eyes, kidneys, nerves, heart, and blood vessels[1]. Type 2 diabetes mellitus is a growing problem in North America affecting about 17 million Americans[2-4]. The prevalence of diabetes has increased rapidly during the last decades[3-5]. Given current trends, the estimated lifetime risk of developing diabetes for US individuals born in 2000 is 32.8% for males and 38.5% for females[6]. Several dietary and lifestyle factors play a role in the etiology and management of type 2 diabetes (Table 1).

Obesity and physical activity

Most of the increase in diabetes prevalence may be attributable to obesity and physical inactivity, which have increased in parallel to the diabetes epidemic[3,7]. Obesity is the strongest risk factor for diabetes. The increased risk of diabetes, as weight increases, has been reported from several prospective studies[8]. Even a BMI at the high end of normal (23.0-24.9 kg/m^2) has been associated with a substantially higher diabetes risk[9]. Physical activity is clearly a cornerstone to weight maintenance. Physical activity, i.e., aerobic exercise, in overweight and obese adults results in modest weight loss independent of the effect of caloric reduction through diet[8]. Furthermore, one clinical trial has provided convincing evidence that increased physical activity can prevent or delay the development of type 2 diabetes[10]. Physical activity has also been identified to be an important factor in preventing cardiovascular complications of diabetes[11-14].

Dietary fats and carbohydrates

Clear evidence from metabolic studies, epidemiologic studies, and clinical trials supports the consumption of unsaturated fats from natural liquid vegetable oils and nuts at the expense of saturated and trans fats in the treatment of various components of the metabolic syndrome (e.g., dyslipidemia, insulin resistance, and glucose intolerance) and in the prevention of diabetes[15]. However, the optimal types and amounts of carbohydrates in the diet remain controversial. It is now well-established that low-fat, high-carbohydrate diets not only lower HDL and raise triglycerides, but can generally produce higher postprandial glucose and insulin responses. Metabolic consequences of carbohydrates depend not only on their quantity but also on their quality. The glycemic response of a given carbohydrate load depends on the food source, which has led to the development of the glycemic index, ranking foods by their ability to raise postprandial blood glucose levels. Although the overall glycemic index of a diet has been found to be associated with an increased diabetes risk in some observational studies, findings are inconsistent so far[16]. The glycemic index might furthermore be a useful concept in the dietary management of diabetes[17]. In addition, effects on blood glucose and lipid metabolism by carbohydrate-rich foods depend on fiber content and type. Controlled feeding studies have found benefits of whole grains on insulin sensitivity and glucose[18] compared to refined grains. In addition, several epidemiologic studies found that diets rich in whole grains may protect against type 2 diabetes[19]. Similarly, cereal fiber has been consistently found to be associated with a reduced risk of diabetes[20]. However, other characteristics of whole-grain foods, besides their high fiber content, might also be important in glucose and lipid metabolism, for example the physical form and degree of processing of whole grains and the presence of micronutrients.

Focus on micronutrients

Magnesium

Magnesium is an important component of whole grains and other unprocessed foods, such as nuts and green leafy vegetables. Its intake has substantially decreased in industrialized countries due to overprocessing of foods and adoption of western diets. Hypomagnesemia is a frequent condition in patients with type 2 diabetes[21]. Hypomagnesemia has been associated with a reduction of tyrosine-kinase activity at the insulin receptor level, which may result in the impairment of insulin action and development of insulin resistance[22]. Oral magnesium supplementation has been shown to improve insulin sensitivity and metabolic control in type 2 diabetic subjects with decreased serum magnesium levels[23]. Although this suggests benefits of magnesium supplementation in the treatment of diabetic subjects, the type, dose, and time of administration of magnesium remains unclear so far and needs further elucidation. Higher magnesium intakes have also been associated with a decreased risk of developing type 2 diabetes[24,25].

Iron

Iron can catalyze the conversion of poorly reactive free radicals into highly active free radicals, which may play a role in the development of diabetes. Iron excess seems to contribute initially to insulin resistance by decreasing glucose uptake by muscles and subsequently to decreased insulin synthesis and secretion in the pancreas[26], and increased total body iron stores have been associated with an increased risk of type 2 diabetes[27]. However, neither total dietary iron intake nor blood donations were associated with risk of type 2 diabetes in a large prospective cohort study of men[28]. In this study, heme-iron intake from red meat was positively associated with the risk of type 2 diabetes. However, the association may have been confounded by other components of red meat intake or dietary exposures associated with it because, heme-iron intake from sources other than red meat (e.g., fish, chicken, and egg) was not associated with the risk of type 2 diabetes. Therefore, although a lower dietary iron intake may be important in the prevention and management of diabetes, there is limited evidence so far supporting this hypothesis. Still, measurement of body iron stores may be helpful in identifying high-risk people who would possibly benefit from lifestyle or therapeutic interventions that can lower iron stores in the body.

Chromium

Although dietary chromium is the main source of chromium in humans, its absorption is poor (≤2.5%). In addition, dietary chromium intake is affected by many factors such as source, processing and method of preparation of foods. Thus, data on food composition are unlikely to provide dietary intake that is a valid measure of the chromium status, and observational studies on dietary chromium intake in relation to diabetes risk are likely to be of little value. Chromium has been demonstrated to increase insulin binding to cells and insulin receptor number and to activate insulin receptor kinase leading to increased insulin sensitivity[29]. In addition, although a recent meta-analysis concluded that there is no effect of chromium supplementation on glucose or insulin concentrations in non-diabetic subjects and that the results for diabetics are inconclusive[30], this meta-analysis neglected clinical trials among diabetic subjects that used chromium picolinate instead of other forms of chromium which are less well absorbed. Chromium picolinate supplementation has been repeatedly shown to have a positive effect on fasting insulin values and on hemoglobin A_{1C} in diabetic patients[31]. Although uncertainties remain with regard to the efficacy of supplementation at different chromium levels and the identification of factors influencing responsiveness to supplementation, chromium supplementation appears to be a promising option for the treatment of persons with insulin resistance or diabetes.

Calcium

Cross-sectional and longitudinal observational studies and small controlled trials in humans suggest that increasing dietary calcium or dairy intake may diminish future weight gain[32]. Although the mechanisms of this effect are not entirely clear, animal models of obesity suggest that dietary calcium intake may conceivably affect the regulation of lipogenesis and lipolysis within adipocytes[32]. In addition to its potential effects on weight gain, dietary calcium has been found to be inversely associated with the incidence of insulin resistance[33]. However, the strong correlation between calcium and dairy intake in observational studies makes it difficult to clearly separate the potential effect of calcium from that of other components of dairy products. Unless the potential benefits of calcium supplementation in preventing or managing insulin resistance are confirmed in controlled trials, the role of calcium in diabetes remains unresolved.

Other dietary and lifestyle factors

An inverse association between coffee consumption and risk of type 2 diabetes has been observed in five prospective cohort studies[34-37], but not in another one[38]. The beneficial effect of coffee consumption on the development of diabetes has mainly been attributed to caffeine, but other constituents of coffee, e.g. potassium, niacin, magnesium and antioxidant substances, may have beneficial effects on glucose metabolism and insulin resistance as well.

Frequent consumption of meat, in particular processed meat, has been shown to increase the risk of diabetes in prospective studies[39].

Moderate alcohol consumption (1-3 drinks/day) has been consistently associated with a 33-56% lower incidence of diabetes and a 34-55% lower incidence of diabetes-related coronary heart disease compared to no alcohol use[40]. However, heavy consumption may be associated with an increased diabetes risk.

Although it has been thought that vitamin E may reduce oxidative stress – a potential contributing factor in the etiology of diabetes and cardiovascular disease – intake from foods and supplements has not been found to be associated with a decrease incidence of diabetes[41]. In addition, vitamin E supplementation had no effect on risk of cardiovascular complications in diabetic subjects in two large clinical trails[42,43].

Several prospective studies have demonstrated that smoking is associated with an increased risk of developing diabetes[44-47]. Furthermore, smoking significantly enhances the risk for cardiovascular disease, contributing to premature morbidity and mortality[48,49]. Smoking is also related to the premature development of microvascular complications of diabetes[50].

Summary and conclusions

Several dietary and lifestyle factors have been identified to be important strategies for the prevention or management of type 2 diabetes, e.g. maintenance of a healthy weight, physical activity, moderate alcohol consumption, substitution of refined carbohydrates by carbohydrates with low glycemic index and high in fiber, and the substitution of saturated and trans fat by unsaturated fat. However, improved knowledge about biological mechanisms and increasing evidence from epidemiologic and clinical studies support that an increased intake of micronutrients like magnesium, calcium, and chromium may be useful strategies as well. Although uncertainties remain, higher intakes of magnesium and chromium seem to offer benefits in the treatment of insulin resistance and diabetes that outweigh by far potential harm.

Table 1. Modifiable risk factors for type 2 diabetes

Lifestyle	Foods	Macronutrients	Micronutrients
Obesity ↑	Processed meats ↑	Fiber ↓	Magnesium ↓
Physical activity ↓	Red meats ↑	Glycemic index/load ↑	Chromium ↓
Smoking ↑	Nuts ↓	Saturated fat ↑	Iron ↑
	Whole grains ↓	Unsaturated fat ↓	Calcium ↓
	Refined grains ↑	Trans fat ↑	
	Coffee ↓	Alcohol ↓	
	Dairy products ↓		

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