Lifestyle interventions and risk of Type 2 diabetes

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ABSTRACT

Diabetes mellitus is one of the most common chronic diseases in nearly all countries. It is difficult to treat and expensive to manage. The development of type 2 diabetes is strongly related to lifestyle factors, thus it might be a preventable disease. Observational studies and intervention trials have shown that physical activity, weight loss and dietary intake including whole grain, dietary fiber and dietary fat are important in delaying and preventing type 2 diabetes. The aim of this review is to gather current information from epidemiologic and clinical trial studies on dietary and lifestyle practices for reducing the risk of type 2 diabetes. The review focuses on the macro and micronutrients, food items and dietary patterns which have been identified as significant in the prevention and management of type 2 diabetes. Also, the role of physical activity and weight loss are presented.

Keywords: Type 2 diabetes; Diet; Nutrition; Lifestyle; physical activity; Weight loss; Diabetes prevention

INTRODUCTION

Diabetes Mellitus is one of the major non-communicable diseases at a global level [1]. It is a major cause of death; blindness; heart and kidney disease; amputations of toes, feet, and legs; and infections [2]. Diabetes patients have a more than twofold increased risk of both micro- and macro-vascular complications leading to high morbidity and mortality [3]. Its serious complications can reduce life expectancy by approximately 10 years [4].

Every 10 seconds, two people in the world will develop diabetes [5]. A worldwide prevalence increasing from 240 million in 2007 to 380 million in 2025 with 80% of the disease burden in low and middle-in- come countries has been estimated [6]. The regions with the highest rates of diabetes are in the eastern Mediterranean and Middle East (9.2% of the adult population has diabetes) [5]. It is currently estimated that 3.6 million people are living with diabetes in Iran [7]. It is considered that more than half (60-90%) of new cases are due to obesity and weight gain [1]. Certainly, unhealthy diet and lifestyle can impose an additional burden on good glycemic control in diabetes patients. Because management of diabetes and its complications imposes enormous medical and economic burdens, focusing on primary prevention has become a public health imperative. Consequently, here is an urgent need for interventions that prevent or delay the development of type 2 diabetes and ameliorate its complications.

In this paper, we gathered and evaluated the current information from epidemiologic and clinical trial studies on dietary and lifestyle practices proposed for reducing the risk of type 2 diabetes. Data for this review were obtained by searching in the Cochrane Library Plus, Wiley, Pubmed, Sciencedirect, Springer and Google Scholar databases with combinations of the following key words: "diabetes" and "diet" or "nutrition" or "physical activity" or "lifestyle".

Macronutrients in diabetes management

Carbohydrates

Total carbohydrate intake is positively and negatively associated with diabetes risk [8-10].

The quality of carbohydrates consumed may be of greater importance than the quantity of intake in determining the ability to raise glucose levels, which depends to a great extent on its influence on gastrointestinal transit and the velocity of nutrient absorption, and the long-term risk of diabetes [11]. Four important qualitative features of dietary carbohydrates relevant to diabetes are fiber, wholegrain seeds, glycemic index (GI), and simple sugars in beverages [12].

Dietary fiber is the indigestible component of complex carbohydrates. Recent results of a meta-analysis showed that high intakes of dietary fiber were associated with a statistically significant improvement in fasting blood glucose and HbA1c in patients with type 2 diabetes mellitus [13].

Soluble viscous fiber plays an important role in decreasing of insulin and plasma glucose, both in healthy people and in type 2 diabetics [14, 15]. It may lower postprandial glycaemia by delaying or by slowing glucose absorption in the gastric empting [16].

An inverse relationship was found between the consumption of fibers from cereals (but not from fruit and vegetables) and diabetes incidence [17-19]. The likely reason is that cereals germ and skin contain many bioactive phytochemicals with potential health benefits [20]. The American Diabetics Association recommends that diabetics and people at risk for developing diabetes should receive 14 g fiber/ 1000 kcal [21]. Several prospective cohort studies have shown a strong inverse relationship between the consumption of whole grain foods and the risk of developing type 2 diabetes [22-24]. Although the mechanisms are unclear, possible mechanisms include a reduced postprandial plasma glucose response and a reduction in oxidative stress [25].

The glycemic index (GI) is an indicator of the average quality of the carbohydrates consumed in terms of glycemic response. Glycemic load (GL) is calculated by multiplying the GI of a food with its carbohydrate content and represents both quality and quantity [3]. GI and GL were associated with an increased risk of diabetes in a meta- analysis of observational studies [26]. A recent prospective cohort showed that diets high in GI, GL and starch and low in fiber were associated with an increased diabetes risk [27]. Furthermore, several randomized controlled trials have shown that low-GI diets improved glycemic control in diabetes patients [28, 29].

Prospective cohort studies have consistently shown that increasing intake of sugar-sweetened beverages relates to a significant increased relative risk of type 2 diabetes [30-32], which is attributable to their effects of promoting insulin resistance due to obesity [33, 34].

Fats

High fat intake has been related to insulin-resistance, while changes in fat content of the diet within the range that people normally consume have little or no effect on insulin-mediated glucose disposal [35]. A recent cohort study has reported that saturated fatty acids (SFA) predict diabetes incidence [36]. The results of cross-sectional and case-control studies have shown that diabetic patients have higher SFA intakes than healthy subjects [37, 38]. Intakes of trans fatty acid cause insulin resistance or break down insulin action and consequently increase the incidence of diabetes [39]. The observational studies have reported association between intake of poly unsaturated fatty acids (PUFA) and improved glysemic control or a reduced risk of diabetes [40- 42]. Long chain n-3 PUFA has not been proved to improve insulin sensitivity or glucose metabolism [42].

Based on the above medicine, the American Diabetics Association recommends that total fat should provide 25-35% of energy intake with SFA<7% and reducing trans fat intake [21].

Protein

A recent large population-based prospective study has indicated that high protein intake is associated with increased risk of type 2 diabetes [43]. But, Hamdy and Horton have reported that higher protein intake does not increase plasma glucose, but increases the insulin response and results in a reduction in HbA1c. Meanwhile, higher dietary protein reduces hunger, improves satiety, and increases thermogenesis [44].

The American Diabetics Association proposes that patients with diabetes and normal renal function should consume 15-20% of their total energy intake from protein [21].

Micronutrients in diabetes management

Minerals

Chromium is an essential trace metal required in the insulin signal cascade [45]. The results of a number of clinical trials show only modest

improvements in markers of insulin resistance and glucose metabolism [46, 47]. Nevertheless, this result has not been definite and the use of chromium supplementation in diabetic patients or in patients at risk for diabetes remains a controversial issue.

Zinc exerts insulin-like effects by supporting the signal transduction response to insulin and by reducing the production of cytokines, which lead to beta-cell death during the inflammatory process in the pancreas [48]. A number of studies have shown that oral zinc supplementation lower levels of oxidative damage [49- 51]. By contrast, a systematic review did not support a role of zinc supplementation in the prevention of type 2 diabetes [52]. A lack of association of oral zinc supplementation with oxidative stress or vascular function has been observed in patients with type 2 diabetes with normal zinc levels [53]. There is currently no evidence to suggest the use of zinc supplementation in the prevention of type 2 diabetes mellitus and more studies are needed.

Magnesium is an essential cofactor for enzyme involved in glucose metabolism [54]. In animal studies, magnesium supplementation reduced the development of diabetes in rat models [55]. Furthermore, the results of randomized controlled studies suggests that magnesium supplementation may exert beneficial effects on glucose control in patients with type 2 diabetes [56] and improve insulin sensitivity in non diabetic subjects [57- 59]. Serum potassium has been found to be a significant predictor of diabetes risk, but the effect of dietary potassium on diabetes risk is not clear [60]. Evidence from the Nurses' Health Study showed a significant association between dietary potassium intake and diabetes risk, adjusting for other traditional risk factors [61]. Although there are a few published studies that have found no significant association between dietary potassium intake and diabetes risk [62, 63], a recent longitudinal study of a cohort of young adults has shown that low dietary potassium is associated with increased risk of incident diabetes in African-Americans [60]. More studies are needed to determine if potassium supplementation could reduce the risk of diabetes, particularly in higher-risk populations.

Vitamins

As diabetes seems to be a state of increased oxidative stress, there has been interest in prescribing antioxidant vitamins in people with diabetes. Vitamin E consists of a family of lipid soluble antioxidant compounds, of which α-tocopherol is the most abundant in the diet [64]. Evidence from some small trials shows no differences in glycemic control with vitamin E supplementation in type 2 diabetics [65- 67]. By contrast, a few trials suggest modest improvements in glycosylated hemoglobin [68, 69]. Vitamin C or ascorbic acid is a water soluble antioxidant vitamin that does not have significant body stores. Dietary intake and plasma levels of vitamin C are lower in diabetic patients than healthy controls [70]. Although, a small randomized trial has shown improvement in glucose disposal rates with vitamin C supplementation [71], other trial failed to show improvement in glucose metabolism or insulin resistance with vitamin C supplementation [72].

Based on the available scientific evidence, routine supplementation with antioxidants such as β-carotene and vitamins E and C is not advised because of lack of evidence of effectiveness and related concern [21].

Some food items in management of diabetes

Milk and dairy products

Dairy products are widely recommended as part of a healthy diet, not only for bone growth and maintenance, but also as protein, calcium and magnesium sources [73]. The results of two large epidemiological studies estimated an annual reduction in diabetes incidence of 9 and 4% in men and women, respectively, with each daily serving of dairy products [74, 75]. In some studies this inverse association was mainly attributed to low-fat dairy consumption [74-76]. The proposed mechanisms that link dairy consumption with type 2 diabetes development includes an insulintropic effect of milk and whey in single meals, the effect of medium chain fatty acids on improving insulin sensitivity, and the effect of peptides, calcium, and other minerals on blood pressure, blood cholesterol and body weight/ fat [76].

Fruit and vegetables

Fruit and vegetables are important components of the dietary patterns associated with a decreased risk of type 2 diabetes [36, 77, 78]. A meta-analysis estimated a significant 14% lower risk of diabetes incidence associated with high green leafy vegetables. No significant relations

were found between the consumption other vegetables, fruit, or fruit and vegetables combined with the incidence of diabetes [79]. Green leafy vegetables might reduce the risk of type 2 diabetes because of their antioxidant and magnesium content [80- 82].

Red meat

Evidence from prospective cohort studies has shown a positive association between high consumption of red meat [83] particularly processed meat (43, 83- 86) with increased incidence of diabetes. Two meta-analysis have assessed the relationship between red meat consumption and diabetes risk [87, 88]. The pooled estimate from 12 cohort studies was that RR (95% CI) of diabetes comparing high vs. low intake was 1.21 (1.07-1.38) for red meat and 1.41 (1.25-1.60) for processed meat [87, 88]. The second meta-analysis pooled the results of 3 cohorts and found that the RRs (95% CIs) were 1.19 (1.04, 1.37) and 1.51 (1.25, 1.83) for 100 g unprocessed red meat/d and for 50 g processed red meat/d, respectively [88]. Substitutions of one serving of nuts, low-fat dairy and whole grains per day for one serving of red meat per day were associated with a 16–35% lower risk of diabetes [88].

Egg

There are limited and inconsistent data on the association between egg consumption and fasting glucose or incident diabetes. The results of a randomized trial have shown that consumption of three eggs per day had no effects on fasting glucose compared with abstention from eggs [89]. By contrast, in the study among Chinese adults, consumption of more than 1 egg/d was associated with significantly elevated risk for diabetes independent of other risk factors for diabetes [90]. In accordance with this finding, a large prospective cohort showed that increased risk of diabetes associated with egg consumption ≥7/wk was 58% in men and 77% in women compared with no egg consumption [91]. Recently, a case-control reported a twofold increased risk of 2 diabetes for individuals consuming 3-4.9 eggs/week (OR = 2.60; 95 % CI 1.34, 5.08) and threefold increased risk of the disease for individuals consuming ≥5 eggs/week (OR = 3.02; 95 % CI 1.14, 7.98) compared with those eating <1 egg/week [92]. It is possible that frequent egg consumption may potentiate the risk of cardiovascular disease by inducing impaired glucose metabolism and insulin resistance [91]. Future investigations are needed to determine the association between egg consumption and diabetes risk and underlying physiological mechanisms.

Coffee

Several recent studies reported that coffee consumption is inversely related to the risk of type 2 diabetes [92- 95]. A meta-analysis pooled the results of 18 prospective studies and indicated that drinking 3-4 cups of coffee per day was associated with an approximate 25% lower risk of diabetes than drinking none or 2 or fewer cups per day (RR, 0.76 [95% CI, 0.69-0.82]). This effect cannot be attributed to caffeine because a similar relationship was also evident in individuals who drank decaffeinated coffee [96]. Coffee components such as chlorogenic acid play a central role, as they can inhibit oxidative stress and inflammation [97].

Tea

Several cohort studies have shown an inverse association between tea consumption and incidence of diabetes [98- 100]. The Pooled estimate from 7 studies indicated that individuals who drank more than 3 to 4 cups of tea per day had an approximate 20% lower risk of diabetes than those consuming no tea (RR, 0.82 [95% CI, 0.73-0.94]) [96]. A similar inverse association was found in other meta-analysis [101]. This beneficial effect may be due to the polyphenols present in tea [100].

Nuts

Nuts are high in fiber and unsaturated fatty acids (PUFAs and MUFAs), which may benefit carbohydrate metabolism by improving insulin sensitivity [102]. The effect of nuts on the risk of developing diabetes is not as conclusive. The Nurses' Health Study cohort showed that consuming nuts five or more times per week reduced diabetes risk by 27% in women, compared to no nuts consumption [103]. By contrast, no association was found between nut/ peanut intake and the risk of developing diabetes in women in Iowa Women's Health Study cohort [104]. Also, the results of the Physicians' Health Study cohort showed no association between nut consumption and diabetes risk in men [105]. Recently, compared to consumption of a healthy diet, a similar diet supplemented with 30 g/d of mixed nuts during 12 weeks was associated with decreased insulin resistance and a borderline improvement in inflammatory markers in patients with MetS in

a randomized trial [106]. More intervention studies are required to demonstrate the protective role on diabetes risk.

Dietary patterns in diabetes management

Western diet

Western pattern is characterized by high intakes of red and processed meats, eggs, sweets and desserts, French fries, refined grains and high-fat dairy products [84]. Evidence from a cross-sectional study showed no association between western diet and risk of diabetes incidence [107]. By contrast, high consumption of refined grains, high-fat dairy, and red meat was associated with an 18% greater diabetes risk in a population-based study [108].

Prudent diet

Prudent pattern is characterized by high intakes of fruit, vegetables, legumes, fish, poultry, whole grains and low- fat dairy products [84]. The results of a population-based study showed that high consumption of whole grains, fruit, nuts/seeds, green leafy vegetables, and low-fat dairy was associated with a 15% lower diabetes risk [108]. Consistent with this finding, several observational studies found an inverse association between diabetes risk and consumption of whole grains [109], nuts/seeds [103], and green leafy vegetables [110]. All of these foods were important components of a prudent pattern.

Mediterranean diet

Mediterranean dietary pattern is characterized by a consumption of fat primarily from foods high in monounsaturated fatty acids and mainly olive oil and daily consumption of fruits, vegetables, low fat dairy products and whole grains, weekly consumption of fish, poultry, tree nuts, legumes, monthly consumption of red meat, as well as a moderate consumption of alcohol [1]. A large prospective study showed that a traditional mediterranean dietary pattern was associated with a significant reduction of 83% in the risk of developing diabetes [111]. Also similar to this finding is that from another cohort study, in which mediterranean dietary pattern was inversely associated with a lower incidence of diabetes in healthy individuals [112]. According to a recent large nutrition intervention trial in spain in 418 nondiabetic subjects, increased adherence to the mediterranean diet was inversely associated with diabetes incidence [12]. The protective effect of mediterranean dietary pattern is attributable to high intake of dietary fiber, antioxidants, polyphenols, magnesium and unsaturated fatty acids. Additionally, this diet is characterized by a low degree of energy density overall, which may prevent weight gain [113].

Table 1. Summary of relationship between lifestyle factors and type 2 diabetes progression

	Increase risk	**Decrease risk**
Macronutrients	Saturated fatty acids Tran fatty acids	Fiber Unsaturated fatty acids
Micronutrients		Antioxidants Magnesium Chromium
Food items	High fat dairy products Meat & meat products Eggs Sugar-sweetened beverages Hydrogenated oils Margarines	Whole grains Pulses Fruit & vegetables Low fat dairy products Nuts Coffee & Tea
Dietary patterns	Western diet High glycemic index diets	Prudent diet Mediterranean diet Low glycemic index diets
Physical activity		Moderate physical activity

Physical activity in diabetes management

Physical activity plays an important role in delaying or preventing development of type 2 diabetes in those at risk [114]. Several observational studies have suggested that higher levels of physical activity are associated with lower risk of diabetes independently of obesity [115-118]. A meta- analysis of randomized controlled trials included information from 377 participants in fourteen randomized controlled trials in comparing exercise against no exercise in type 2 diabetes. This meta-analysis showed

that the exercise intervention significantly improved glycaemic control as indicated by a decrease in glycated haemoglobin levels of 0.6% and increased insulin response [119]. Another meta-analysis of 10 prospective cohort studies indicated that individuals who regularly engaged in physical activity of moderate intensity had 30% lower risk of type 2 diabetes as compared with sedentary individuals [120].

Benefits of physical activity are numerous and include aiding weight loss and weight maintenance and improving the insulin sensitivity insulin, muscle glucose uptake and utilization, and overall glycemic control [121-124].

CONCLUSION

The incidence of type 2 diabetes is increasing rapidly worldwide. Lifestyle intervention such as dietary modification and physical activity play a significant role in diabetes prevention and management. According to the existent evidence, as summarized in Table 1, a healthy diet including wholegrain, fruit and vegetables, low fat dairy products, nuts and foods rich in monounsaturated fatty acids and avoiding simple sugars and foods rich in saturated fatty acids (such as meat and meat products) and trans fatty acids (such as hydrogenated oils and margarines), and drinking reasonable amounts of coffee and tea bears a lot of potential in controlling diabetes and attenuating its progression. Consequently, emphasis should be given on encouraging individual for adopting a healthy lifestyle in order to prevent the development of type 2 diabetes.

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