Study on food nutrition and association with Diabetes Mellitus

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ABSTRACT: The increasing number of diabetic patients is becoming a worldwide problem. In recent decades, type 2 diabetes mellitus (T2DM) has been prevalent significantly in the Asian-Pacific region. This may be caused due to modern lifestyle and western dietary patterns, such as reduced physical activity, increased consumption of fat and sugar. In this article, we described various dietary nutritions and their relationships with diabetes, particularly T2DM. We reviewed recent studies on dietary fat, dietary proteins, dietary carbohydrates and dietary supplements regulating diabetes prevention and control. These epidemiological and experimental findings are expected to provide further insight for controlling and treating diabetes in modern nutritional background.

1. INTRODUCTION
The International Diabetes Federation has released the latest edition of its Global Diabetes Overview, which states that by 2019, in total, there are about 463 million people with diabetes by the age of 79, with China ranking first in the number of people with diabetes, with a total of about 116.4 million people, the second is India with about 77 million diabetics, and the third is the United States with 31 million diabetics patients. According to the estimate, China and the United States spend $294.6 billion and $109 billion, respectively, on diabetes-related health expenditures. And the annual number of deaths due to diabetes in China is about 834,000[1].

Diabetes is a disease caused by endocrine and metabolic disorders of nutrients in the body. These two disorders interact with each other as both cause and effect, causing many important biochemical reactions in the body to be out of regulation. The current research on the nutritional factors of diabetes is mainly focused on the influence of nutrient metabolism, especially the metabolism of carbohydrates and fats. Patients with diabetes have limited intake of sugars, staple foods and fruits, and the metabolism of substances in the body is relatively vigorous, so vitamin and mineral deficiencies are more likely to occur. Therefore, it is of vital importance to pay attention to the balance of nutrition in the diet, which is helpful to correct the metabolic disorders of diabetic patients and prevent diabetic complications.

2. Food nutrition
Nutrients are substances that can support human normal physical activities. The modern nutrition therapy divided nutrients into 7 categories: Carbohydrate (CHO), Protein, Fats, Vitamins, Minerals, Water and Dietary Fiber. It is known that there are 40-45 essential nutrients for the human body, which all exist in the food. Carbohydrates, protein and fats are known as three macronutrients.
2.1 Carbohydrate (CHO)
Carbohydrates are a common part of the diet. Sugars, fibers and starches are the most common and abundant forms. CHO provide glucose to the human body, and glucose is converted into energy to support body function and physical activity.

2.2 Protein
Protein is the foundation of organs, muscles, skin, and hormones. All cells in the human body contain protein, which is the main structural substance of human cells. Essential amino acids are amino acids that humans must obtain from the diet and cannot be synthesized by themselves. There are 9 of them. Protein in the diet is mainly found in animal products, and can also be found in legumes and nuts.

2.3 Fats
Dietary fat, also known as fatty acids (FAs), can be found in foods from both plants and animals. FAs can be divided into saturated FAs, trans unsaturated FAs and cis unsaturated FAs. Fats are the most efficient form of energy storage in human body. Besides, they can also make contribution to transport fat-soluble vitamins, like vitamin A, D, E, in body.

2.4 Vitamins
Vitamin is an essential micronutrient which can be classified into water-soluble and fat-soluble. For the most part, they can be obtained from the diet. Proper intake amount is important, because some vitamins have acute or chronic toxicity at larger intakes.

2.5 Minerals
There are two kinds of minerals: macrominerals, which include phosphorus, magnesium and calcium etc., and trace minerals, including iodine, copper, iron and so on.

2.6 Dietary Fiber
Dietary fiber refers to the part of plant food that cannot be decomposed by human digestive system. It has two main categories: soluble fiber and insoluble fiber.

3. Diabetes Mellitus
Diabetes Mellitus (DM) is a kind of metabolic disease featured with long-term hyperglycemia.

3.1 Diagnosis
Glucose tolerance has 3 classifications, which are normal glucose homeostasis, impaired glucose homeostasis, and diabetes mellitus respectively.

As shown in TABLE 1, glucose tolerance can be tested by, oral glucose challenge, hemoglobin A1C (A1C) or fasting plasma glucose (FPG). FPG <5.6 mmol/L (100 mg/dL), plasma glucose after oral glucose challenge <140 mg/dL (11.1 mmol/L), and A1C <5.6% are regarded as normal glucose tolerance. FPG 7.0 mmol/L (126 mg/dL), 2 hours after oral glucose challenge blood glucose >11.1 mmol/L (200 mg/dL), or A1C 6.5% can be diagnosed DM.

| Type of Diabetes | Normal glucose tolerance | Pre-diabetes | Diabetes Mellitus |
|-----------------|--------------------------|--------------|------------------|
| FPG             | <5.6mmol/L (100 mg/dL)   | 5.6-6.9mmol/L (100-125 mg/dL) | ≥7.0mmol/L (126mg/dL) |
| 2-h PG          | <7.8 mmol/L (140 mg/dL)  | 7.8-11.0mmol/L (140-199 mg/dL) | ≥11.1mmol/L (200 mg/dL) |
| A1C             | <5.6%                    | 5.7-6.4%     | ≥6.5%            |

Table 1. The Diagnosis of Diabetes Mellitus
Prediabetes refers to blood sugar levels higher than normal, but not to the extent that diabetes can be diagnosed. The disease can be considered as impaired glucose tolerance or impaired fasting blood glucose. Almost all type 2 diabetic patients have prediabetes. The treatment of prediabetes is the key to prevent more serious development.

3.2 Classification
Diabetes Mellitus is classified according to the pathogenesis that cause high blood sugar. Two main types of DM are type 1 and type 2. Other forms of DM include genetic defects in beta cell function or insulin action as well as gestational diabetes.

Characteristics type 1 DM (T1DM) is a reduction of beta cells, a kind of insulin-producing cell, which could lead to insulin deficiency. The disease is partly inherited and has multiple genes. In genetically susceptible population, the incidence of diabetes may be resulted from one or more environmental causes, for example viral infections or dietary factors.

Type 2 DM (T2DM) is characterized by insulin resistance. Many T2DM patients show prediabetes before diagnosed as diabetes. As the most common form of diabetes mellitus, T2DM is mainly due to genetics and lifestyle causes, for example obesity, poor dietary factors and little exercise.

Gestational diabetes mellitus occurs in pregnant women without a previous history of diabetes. Untreated GDM can be harmful to both mother and fetus, which includes high risk of macrosomia, increased insulin level to the baby.

3.3 Diabetes Complication
Diabetes complications can be divided into acute complications and chronic complications. Typical acute complications include diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar state (HHS).

Chronic complications of DM influence many organ systems, which is the main cause of condition and death. The risk of chronic complications with the duration and extent of high blood sugar increases, usually to the second decade of hyperglycemia will be revealed. Because type 2 DM often has high blood sugar asymptomatic in a long time, lots of patients with complications have already occurred when diagnosed.

4. Nutrition therapy and DM prevention
The two most important non-drug treatments in diabetes prevention and treatment are nutrition and exercise, and nutrition is focused on in this article. For people with DM and pre-diabetes, especially in the pre-diabetic population, a healthy scientific approach can prevent and reverse condition. Specifically, the distribution of energy intake across the macronutrients should be paid attention to. The total intake of CHO should be 60% of the total energy intake, and the portion of fat should be 25%. As glyconeogenesis in diabetic patients is active, the consumption of protein increases. Thus, dietary protein intake should be adequate, making up 15-20% of the total energy intake. The American Diabetes Association has recommended 10 super foods for diabetes diets as shown in FIGURE1.
4.1 Dietary Fat
The relationship between dietary fat intake and risk of T2DM is still controversial. However, one thing is clear: different types of FAs and various sources of dietary fat show diverse effect on human metabolism and health.

Dietary fat intake is increased insulin resistance related. FAs can induce fatty acid oxidation and insulin secretion in the absence of glucose, but to a lesser extent. However, when glucose is present, high concentration of malonyl-CoA will be produced by Fas, leading to the increased insulin release. Long-term exposure to FAs and glucose can lead to glulipotoxicity and reduced insulin release. However, it is unclear whether gene and diet can regulate this association[2]. Amount of dietary fat intake, not its composition, mainly determines the development of acute insulin resistance.

Baseline intake of SFA and animal fat are not linked with T2DM incidence. High SFA intake has been associated with increased CVD and T2DM risk, resulting from adipose tissue inflammation and alternations in cholesterol homeostasis. SFA intake will rapidly increase insulin resistance, hepatic lipid storage and energy metabolism. Moreover, it is preferable to PUFA for fasting insulin and glucose lowering[5].

PUFA is related to improving blood sugar, insulin resistance, and insulin secretion. It has more positively significant effect than other macronutrients, like SFA, MUFA, or carbohydrate[6]. PUFA, especially DHA and EPA, is related to health benefits, involving anti-inflammatory effects. Some strong evidences also suggest that polyunsaturated fatty acid (PUFA) have a positive effect on preventing and relieving diabetes. Improving fat quality, like consuming more MUFA and omega 3 PUFA might improve blood glucose, serum insulin, inflammatory markers and hepatic fat[7]. For example, the Asian population consumes fish and marine N-3 PUFA and the western population consumes dairy foods and trans-palmitoleic acid. These two may be linked with reducing risk of T2DM.[8]

Recent studies have shown that FAs from the same category but from different sources may have different associations with the risk of T2DM. There are signs that plant-based FAs have a lower risk of T2DM, while animal-based risks are higher[9]. Meat intake is related to increased risk, regardless of fat content. Dose-response analyses showed that for every unit increase in total dairy and low-fat dairy
intake, the risk of T2DM was reduced[10]. Total dairy product intake is related to reducing the risk of T2DM, especially yogurt and low-fat dairy products. Cheese and butter intake is related to a higher risk of T2DM[11]. Furthermore, there may be differences between people in different regions, but no interactive effect of fat intake and genetic susceptibility on T2DM risk has been observed[9].

4.2 Dietary Protein
The association between dietary protein and the incidence of T2DM is still conflicting. The recommended amount and quality of dietary protein of people with diabetes mellitus are highly controversial. The recommendation for protein intake depends on the individual health status. In general, for T2DM patients, it is sufficient to strive for protein to account for 20-30% of the total energy. For the elderly, the protein demand should be higher.

Dietary protein has effect on lipid metabolism. Regardless of the source, a high-protein diet can significantly reduce liver fat, reduce markers of hepatic necroinflammation and insulin resistance. The diets seem to achieve these changes through lipolytic and lipogenic pathways in adipose tissue[12]. A diet rich in plant protein reduced either total cholesterol or LDL cholesterol or apolipoprotein B according to several studies[13]. Whey protein can improve lipid metabolism, its role is to reduce post-prandial triglyceride reaction[14]. Dietary protein will control gene expression, including insulin secretion, through a series of molecular pathway. Also, bioactive compounds in the diet such as isoflavones play an essential role in controlling insulin secretion.

The protein in the diet is an important regulator of glucose metabolism and other mechanisms. A higher consumption of plant protein is linked with a modest reduction in risk. A diet high in animal protein is associated with an increased risk of diabetes. Ingesting 5% of energy from total protein or animal protein, and sacrificing 5% of energy from carbohydrates or fat will increase the risk of diabetes[15]. Substitution of protein based on plant and yogurt for animal protein, especially processed meat and red meat, can lower the incidence of T2DM[16]. Besides, observational studies provide evidence that a higher intake of vegetable protein and certain animal protein is associated with a lower risk for T2DM[17].

A higher intake of dairy products always has a positive effect on glucose regulation. The clinical evidence regarding both dairy foods and dairy products are likely to improve insulin secretion in people with T2DM[18, 19]. This is because it contains large amounts of whey proteins and is abundant in branched-chain amino acids(BCAAs), which can reduce glycemic responses after meals, promote insulin secretion, besides, also act to reduce postprandial triglyceride response[14, 20]. Dairy protein-derived peptides may also inhibit activity through dipeptidyl peptidase-4(DPP-4) which helps to exert the effect of insulin and may reduce the blood pressure[14]. The use of DPP-4 inhibitors is an emerging method for the treatment of T2DM[21]. Fermentation of dairy products with probiotics has other beneficial effect on health. Clinical evidence indicates that yogurt is involved in controlling body weight and energy balance, and is likely to have effect on reducing the risk of T2DM partly via alteration in gut microbiota, appetite control and so on.

4.3 Dietary Carbohydrates
The advantages of carbohydrate restriction in diabetes are immediate and widely accepted, in spite of the uncertainty about the long-term effect of low carbohydrate diet or the optimal quantity and quality. According to many studies, low carbohydrate diet shows significant effect, including weight loss, reducing diastolic blood pressure, and increasing total cholesterol and high-density lipoprotein cholesterol[22]. Therefore, dietary carbohydrate restriction can reduce high blood glucose and reduce or even eliminate medication. Besides, it has not shown side effects as those seen in many drugs yet[23, 24].

Two types of diets are well known as carbohydrate restriction strategies. The ketogenic diet, which is characterized by high fat intake, low carbohydrates intake, has shown benefits for individuals with obesity and diabetes in recent clinical research. This diet greatly reduces the blood sugar response
caused by carbohydrate in the diet, and also improves potential insulin resistance[25]. Similarly, Mediterranean diet has also recently become popular among the diabetic population. The Mediterranean diet is featured with a primarily plant-based dietary pattern, consumption of olive oil and a moderate amount of red wine. There is evidence that diabetic patients can indeed gain cardiovascular benefits from a Mediterranean diet. It shows that this diet style may also have a positive effect on preventing T2DM and reducing HbA1c in persons with established diabetes. Also, the Mediterranean diet can help improve memory function among adults without T2DM[24].

High dietary fiber intake is an important part of diabetes management, and can improve the measurement of blood sugar control, blood lipids, body weight, and inflammation. These benefits are not restricted to the type of fibers and diabetes [26-28]. Moreover, vegetable and fruit consumption may protect against the development of T2DM. A 4-year longitudinal study conducted among Swedish adults showed that adults with low vegetable intakes has a 62% higher risk of developing T2DM compared to high intakes. Increase intake of vegetables and fruits should be a priority for public health[27].

4.4 Dietary Supplements

Recently, many people believe that dietary supplements are more controllable and may be more effective than medications for T2DM. However, the use of dietary supplements to reduce or control diabetes is little clinical evidence. Several popular dietary supplements, as such w-3 fatty acid, aspirin, vitamin D and chromium did not show significant effect on disease control and treatment[29-32]. Oral Mg supplementation plays a role on improving HbA1C and insulin levels according to several studies[33].

Herbal supplements have been used for a long period and some of them indeed show significant effects in T2DM. Cinnamon, as a traditional treatment in China for thousands of years, can greatly ameliorate blood sugar control in patients with T2DM in China[34]. Beyond that, the intake of cinnamon in other countries has also achieved some promising results in controlling T2DM.

Some recent researches have suggested that consuming probiotics, especially Lactobacillus and Bifidobacterium spp., may have beneficial impact on controlling T2DM[35]. In terms of the recent studies, the use of probiotic supplements can lower blood glucose and increase antioxidant enzymes in T2DM patients[36]. Moreover, it also shows effect on lowering fasting glucose and increasing insulin sensitivity in patients with gestational diabetes[37].

Traditional Chinese tea has many pharmacological effects. Recent studies also showed that drinking tea may show benefits on reducing T2DM risk. In terms of a study in 2020, the findings indicated that women, the elderly, and obese people drink tea every day is negatively correlated with the risk of diabetes[38]. These studies have opened a new area of dietary supplements investigation for diabetes prevention in China.

5. Conclusions

Exploring the relationship between nutrients and T2DM still requires continued efforts by future scientists. More scientific approaches are needed, including clinical trials, randomized trials, double-blind trials and more. Deeper research is still needed. More flexible, convenient and accurate means of blood glucose testing are also needed as technology advances in the medical field.

The development of individualized nutritional plans for different patients is something that should be pursued in the future, although this is difficult because the customized nutritional plans vary depending on the patient’s gender, region of life, dietary habits, patient genetic factors and health status.

In the future, government policy intervention is expected to control the risk of diabetes. The public still learn about knowledge about diabetes insufficiently, therefore, the pervades of diabetes education should be achieved in the near future.
REFERENCES

[1] Jia, W., et al., Standards of medical care for type 2 diabetes in China 2019. Diabetes Metab Res Rev., 2019. 35: p. e3158.

[2] Huang, T., et al., Association Between Dietary Fat Intake and Insulin Resistance in Chinese Child Twins. Br J Nutr, 2017. 117(2): p. 230-236.

[3] Alkhatib, A., C. Tsang, and J. Tuomilehto, Olive Oil Nutraceuticals in the Prevention and Management of Diabetes: From Molecules to Lifestyle. Int J Mol Sci, 2018. 19(7): p. 2024.

[4] Sarabhai, T., et al., Monounsaturated Fat Rapidly Induces Hepatic Gluconeogenesis and Whole-Body Insulin Resistance. JCI Insight, 2020. 5(10).

[5] Clifton, P., Metabolic Syndrome-Role of Dietary Fat Type and Quantity. Nutrients, 2019. 11(7): p. 1438.

[6] Imamura, F., et al., Effects of Saturated Fat, Polyunsaturated Fat, Monounsaturated Fat, and Carbohydrate on Glucose-Insulin Homeostasis: A Systematic Review and Meta-analysis of Randomised Controlled Feeding Trials. PLoS Med, 2016.

[7] Gulati, S. and A. Misra, Abdominal Obesity and Type 2 Diabetes in Asian Indians: Dietary Strategies Including Edible Oils, Cooking Practices and Sugar Intake. Eur J Clin Nutr, 2017. 71(7): p. 850-857.

[8] Bradley, B.H.R., Dietary fat and risk for type 2 diabetes: A review of recent research. Curr Nutr Rep, 2018. 7(4): p. 214-226.

[9] Schlesinger, S., L. Schwingshackl, and M. Neuenschwander, Dietary Fat and Risk of Type 2 Diabetes. Curr Opin Lipidol, 2019. 30(1): p. 37-43.

[10] Alvarez-Bueno, C., et al., Effects of Milk and Dairy Product Consumption on Type 2 Diabetes: Overview of Systematic Reviews and Meta-Analyses. Adv Nutr, 2019.

[11] Drouin-Chartier, J.-P., et al., Changes in Dairy Product Consumption and Risk of Type 2 Diabetes: Results From 3 Large Prospective Cohorts of US Men and Women. Am J Clin Nutr, 2019. 110(5): p. 1201-1212.

[12] Markova, M., et al., Isocaloric Diets High in Animal or Plant Protein Reduce Liver Fat and Inflammation in Individuals With Type 2 Diabetes. Gastroenterology, 2017. 152(3): p. 571-585.

[13] Pfeiffer, A.F.H., et al., The Effects of Different Quantities and Qualities of Protein Intake in People With Diabetes Mellitus. Nutrients, 2020. 12(2): p. 365.

[14] Bjørnshave, A. and K. Hermansen, Effects of Dairy Protein and Fat on the Metabolic Syndrome and Type 2 Diabetes. Diabetes Care, 2014. 11(2): p. 153-66.

[15] Sluijs, I., et al., Dietary Intake of Total, Animal, and Vegetable Protein and Risk of Type 2 Diabetes in the European Prospective Investigation Into Cancer and Nutrition (EPIC)-NL Study. 2010. 33(1): p. 43-8.

[16] Fan, M., et al., Dietary Protein Consumption and the Risk of Type 2 Diabetes: A Dose-Response Meta-Analysis of Prospective Studies. Nutrients, 2019. 11(11): p. 2783.

[17] Comerford, K.B. and G. Pasin, Emerging Evidence for the Importance of Dietary Protein Source on Glucoregulatory Markers and Type 2 Diabetes: Different Effects of Dairy, Meat, Fish, Egg, and Plant Protein Foods. Nutrients, 2016. 8(8): p. 446.

[18] Pasin, G. and K.B. Comerford, Dairy Foods and Dairy Proteins in the Management of Type 2 Diabetes: A Systematic Review of the Clinical Evidence. Adv Nutr, 2015. 6(3): p. 245-59.

[19] O'Connor, S., et al., Increased Dairy Product Intake Modifies Plasma Glucose Concentrations and Glycated Hemoglobin: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Adv Nutr, 2019. 10(2): p. 262-279.

[20] Chartrand, D., et al., Influence of Amino Acids in Dairy Products on Glucose Homeostasis: The Clinical Evidence. Can J Diabetes, 2017. 41(3): p. 329-337.

[21] Power, O., et al., Food Protein Hydrolysates as a Source of Dipeptidyl Peptidase IV Inhibitory Peptides for the Management of Type 2 Diabetes. Proc Nutr Soc, 2014. 73(1): p. 34-46.
[22] Fechner, E., et al., The Effects of Different Degrees of Carbohydrate Restriction and Carbohydrate Replacement on Cardiometabolic Risk Markers in Humans-A Systematic Review and Meta-Analysis. Nutrients, 2020. 12(4): p. 991.

[23] D., F.R., et al., Dietary Carbohydrate Restriction as the First Approach in Diabetes Management: Critical Review and Evidence Base. Nutrition, 2015. 31(1-13).

[24] Huntriss, R., M. Campbell, and C. Bedwell, The Interpretation and Effect of a Low-Carbohydrate Diet in the Management of Type 2 Diabetes: A Systematic Review and Meta-Analysis of Randomised Controlled Trials. Eur J Clin Nutr, 2018. 72(3): p. 311-325.

[25] Westman, E.C., et al., Implementing a Low-Carbohydrate, Ketogenic Diet to Manage Type 2 Diabetes Mellitus. Expert Rev Endocrinol Metab, 2018. 13(5): p. 263-272.

[26] Chandalia, M., et al., Beneficial Effects of High Dietary Fiber Intake in Patients With Type 2 Diabetes Mellitus. N Engl J Med, 2000. 342(19): p. 1392-8.

[27] Post, R.E., et al., Dietary Fiber for the Treatment of Type 2 Diabetes Mellitus: A Meta-Analysis. J Am Board Fam Med, 2012. 25(1): p. 16-23.

[28] Reynolds, A.N., A.P. Akerman, and J. Mann, Dietary Fibre and Whole Grains in Diabetes Management: Systematic Review and Meta-Analyses. PLoS Med, 2020. 17(3).

[29] Costello, R.B., J.T. Dwyer, and R.L. Bailey, Chromium Supplements for Glycemic Control in Type 2 Diabetes: Limited Evidence of Effectiveness. Nutr Rev, 2016. 74(7): p. 455-68.

[30] Pittas, A.G., et al., Vitamin D Supplementation and Prevention of Type 2 Diabetes. N Engl J Med, 2019. 381(6): p. 520-530.

[31] Bowman, L., et al., Effects of Aspirin for Primary Prevention in Persons With Diabetes Mellitus. N Engl J Med, 2018. 379(16): p. 1529-1539.

[32] Bowman, L., et al., Effects of n-3 Fatty Acid Supplements in Diabetes Mellitus. N Engl J Med, 2018. 379(16): p. 1540-1550.

[33] ELDerawi, W.A., et al., The Effects of Oral Magnesium Supplementation on Glycemic Response Among Type 2 Diabetes Patients. Nutrients, 2018. 11(1): p. 44.

[34] Lu, T., et al., Cinnamon Extract Improves Fasting Blood Glucose and Glycosylated Hemoglobin Level in Chinese Patients With Type 2 Diabetes. Nutr Res, 2012. 32(6): p. 408-12.

[35] Salgaço, M.K., et al., Relationship between gut microbiota, probiotics, and type 2 diabetes mellitus. Applied Microbiology and Biotechnology 2019. 103: p. 9229-9238.

[36] Mirmiranpour, H., et al., Effects of Probiotic, Cinnamon, and Synbiotic Supplementation on Glycemic Control and Antioxidant Status in People With Type 2 Diabetes; A Randomized, Double-Blind, Placebo-Controlled Study. J Diabetes Metab Disord, 2019. 19(1): p. 53-60.

[37] Kijmanawat, A., et al., Effects of Probiotic Supplements on Insulin Resistance in Gestational Diabetes Mellitus: A Double-Blind Randomized Controlled Trial. J Diabetes Investig, 2019. 10(1): p. 163-170.

[38] Chen, Y., et al., Tea Consumption and Risk of Diabetes in the Chinese Population: A Multi-Centre, Cross-Sectional Study. Br J Nutr, 2020. 123(4): p. 428-436.