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Metabolic Effects of Dietary Fiber, Carbohydrate, Glucose, Lipid Metabolism on Human Health and Nutritional Therapy

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The majority of diabetic and nutrition groups recommend a diet rich in dietary fibre (DF). Soluble DF is known to have favourable effects on certain blood lipids, decrease the postprandial glucose response, and restrict macronutrient absorption due to its viscous and gel-forming characteristics. While there appears to be no discernible difference in the regulation of body weight between soluble and insoluble DF consumption, the fermentation of naturally occurring high-fiber foods in the colon is mostly caused by soluble DF. Nevertheless, prospective cohort studies have consistently linked insoluble cereal DF and whole grains—rather than soluble DF—to a lower risk of diabetes, indicating that additional, as-yet-unidentified mechanisms are probably at work. New evidence suggests that DF consumption does more than just affect weight. It also improves insulin sensitivity, modifies the secretion of gut hormones, and affects metabolic and inflammatory markers linked to metabolic syndrome, among other surprising metabolic effects. A common dietary strategy for improving hyperglycemia and diabetes is increasing consumption of dietary fibre, which consists of indigestible polysaccharides. Dietary fibres like guar, inulin, cellulose, and pectin have been shown to regulate glucose metabolism, according to numerous studies. Another new dietary fibre that reduces postprandial glycemia is an indigestible polysaccharide. A lot of people are curious about how fibre affects carbohydrate metabolism because someone said that diabetes should be one of many Western diseases linked to not getting enough fibre. 1 Research on fiber's effects on diabetes has only served to fuel interest in this field. Researchers Anderson and Ward3 and Kiehm et al.2 discovered that low-insulin diabetes patients' insulin needs were alleviated when they followed high-carbohydrate, high-fiber diets. No matter the insulin dosage, Jenkins et al.4,5 found that diabetics' glycosuria decreased when guar gum was added to their diet. Miranda and Horwitz6 found that diabetics whose breads were high in cellulose had a more consistent glucose profile throughout the day. Developing medications for diabetics that aim to change small-intestinal events became possible as a result of these investigations. They also offered a chance to study and improve the overall glucose metabolism that came from these alterations. Consequently, research into the physicochemical features that may influence glucose tolerance and the kinds of dietary fibre that may have the greatest impact on this area has been accelerated.

Keywords: Nutritional Therapy, Metabolic, Dietary Fiber, Metabolism

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Introduction

High blood glucose levels are a hallmark of the many chronic metabolic diseases that go under the umbrella term diabetes mellitus. Nearly 124 million people across the globe were diabetic in 1997, with nearly all of those people suffering from type 2 diabetes, also called adult-onset diabetes or non-insulin-dependent diabetes mellitus (NIDDM). About 17% of adults over the age of 65 have type 2 diabetes, making it the most common kind of the disease in adults overall. An estimated 8 percent of the United States' overall health care spending is attributable to type 2 diabetes, which has risen to the position of fourth or fifth major cause of death in these countries. An intricate chain reaction begins with impaired insulin action, progresses via increased insulin secretion to compensate, and finally culminates in pancreatic beta-cell loss as a possible cause of diabetes. Hyperglycemia persists after beta-cell dysfunction sets established. We still don't know enough about the underlying defect(s), but we've come a long way in comprehending the cellular processes that begin when insulin binds to its receptor [1-3]. There have been several identified faults in the different cellular responses to insulin, but there will surely be more discoveries as our understanding of insulin's deep and nuanced cellular functions grows. All throughout the globe, people are coming up with new nutritional and medicinal treatments to help with glucose metabolism diseases, particularly diabetes and hyperglycemia. Dietary fibre reduces the rise in plasma glucose levels after a meal, making it a potential nutritional treatment for these conditions. Compared to a single carbohydrate intake, consuming vegetables—which are rich in dietary fiber—prior to carbohydrate consumption reduced postprandial glycemia in both healthy individuals and those with type 2 diabetes. Reports of improved glucose metabolism by dietary fibres such cellulose, pectin, guar, and inulin date back to the 1970s. Cellulose, a homopolysaccharide composed of hundreds to thousands of β1-4 glycosidic-bound D-glucose units, is an essential structural component of plant cell walls. Apples and citrus fruits contain pectin, a heteropolysaccharide [4, 5]. Galacturonic acid was its primary ingredient. The galactomannan polysaccharide guar is derived from guar beans and goes by several names, including guar gum. Reportedly, these three polysaccharides reduce small intestine glucose absorption, therefore attenuating the rapid rise in postprandial plasma glucose levels. In an effort to decipher these processes, scientists have postulated that dietary fibres thicken the rate-limiting unstirred layer and raise the luminal fluid viscosity in the intestines. Consequently, these actions reduce the serosal side's ability to absorb glucose from the luminal side. The heteropolysaccharide inulin is most commonly found in chicory and Jerusalem artichokes. Its primary building blocks are fructose units and fructans that have a glucose terminal. Reports indicate that inulin consumption can lower postprandial glycemia over an extended period of time, around one to two months. It has only recently been understood how dietary fibre helps with glucose metabolism issues [6-10]. When it comes to controlling type 2 diabetes, the gut microbiota is seen as an indicator. The composition of the microbiota and the relative populations of bacterial species can be altered by consuming dietary fibres and the short-chain fatty acids (SCFA) that are formed from these fibres through bacterial fermentation in the colon. Additionally, it was said in these articles that SCFA helps type 2 diabetics become more insulin sensitive. Furthermore, by enhancing the gut flora, inulin reduces hyperglycemia in diabetic mice, according to Shao et al. According to these research, SCFA has a crucial role in regulating the gut microbiota's role in the dietary fiber-mediated treatment of diabetes [11, 12]. Our long-term goal is to learn more about the molecular pathways that link SCFT to better diabetes management. Researchers have found that a number of novel dietary fibres can control blood sugar levels. Isomaltulose (IMD) is one of them. Enzymatic and artificial production of starch yields IMD, a highly branched α-glucan. By inhibiting the intestinal glucose transfer from the mucosal side to the serosal side and the activities of carbohydrate-digestive enzymes, Sadakiyo et al. (2017) discovered that IMD reduced the postprandial rise of plasma glucose levels. Proteoglycans (PG) are novel ingestible polysaccharide-like substances that control glucose metabolism; their discovery was made in 2015 by Tsuchiya et al. In several extracellular matrix components, including skin and cartilage, PG plays a crucial role that does not involve collagen. Even though it wasn't originally intended for human consumption [13, 14], PG was extensively refined from salmon nasal cartilage for use in both medicine and cuisine. Researchers Tsuchiya et al. observed that rats whose oral intake of salmon PG was reduced had lower increases in plasma glucose levels, likely due to a reduction in glucose absorption in the jejunum. Chondroitins

A and C are the main components of these GAG chains. Agrecans, like salmon PG, have GAG chains that are both very hydrophilic and negatively charged. These chains may inhibit glucose absorption by conjugating glucose.

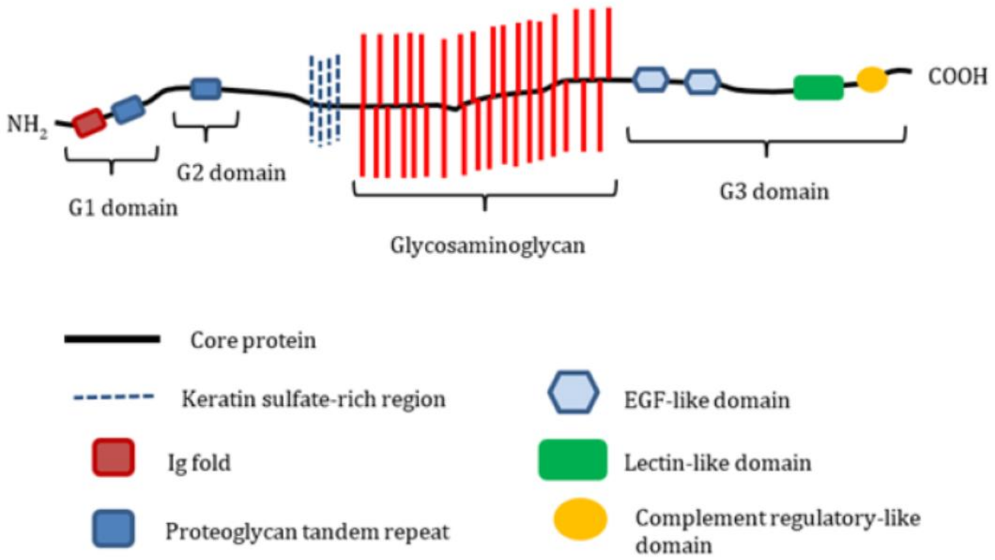

Figure 1. structure of aggrecan.

An international public health emergency, the incidence of diabetes has increased dramatically during the past few decades. Type 2 diabetes mellitus (T2DM) affects 90% of the 537 million individuals in the 20-79 age group who have diabetes, according to the 10th Edition of the International Diabetes Federation report from 2021. One of the many comorbidities closely associated with type 2 diabetes is cardiovascular disease (CVD). This systemic metabolic disorder is marked by insulin resistance, poor glucose tolerance, persistent hyperglycemia, and hyperinsulinemia. The number of cases is projected to keep rising and might surpass 642 million by 2040 if no action is taken. Because of fast socioeconomic development, an increase in sedentary lifestyles, and overnutrition, this event will disproportionately affect many low- and middle-income countries in Asia [15-18]. Dietary habits are modifiable factors that impact both glycaemic control and problems connected to type 2 diabetes, thus regulating them is an important part of therapeutic methods for managing the disease and preventing comorbidities. As a result, the principalstay of therapy for type 2 diabetes is now dietary modification and medication treatment to reduce glucose levels [7]. To accomplish the intended therapeutic goals, the two treatment modalities work in tandem. Consequently, finding effective dietary changes to include in pharmaceutical treatments for type 2 diabetic patients is an immediate priority. Prior research has mostly ignored the potential for pharmaceutical interventions and food intakes to have synergistic or interaction effects in favour of evaluating each component independently in epidemiological or clinical trials. The Metformin and Acarbose in Chinese as the first Hypoglycemic Therapy (MARCH) trial was the first to examine the impact of dietary variables on glycaemic control while taking antidiabetic medication, filling a gap in the existing data. Macronutrient consumption may have an effect on the effects of acarbose and metformin on cardiometabolic risk factors and glycaemic management, as we have previously investigated [19, 20]. Following a carbohydrate-restricted diet led to additional weight loss and glycaemic control benefits, as we found that high carbohydrate consumption was independently and significantly correlated with higher BMI, HbA1c, PPG, and AUC for serum insulin. But there's mounting evidence that the type of carbs eaten (i.e., a focus on high-fiber carbs and an ideal fibre percentage of total carbs) matters more than carb quantity when it comes to the impact of diet on blood sugar regulation and weight maintenance. Here, dietary fibres show great potential as an important nutrient for type 2 diabetes prevention and treatment. An effective technique for easing type 2 diabetes, according to reports from epidemiology and clinical intervention trials, is increased consumption of dietary fibre, especially among patients with inadequate intakes. The evidence review process is complicated by the heterogeneity of dietary fibre sources and their relative contributions to total carbohydrate consumption; different types of fibre have different structural and physicochemical properties and may provide different health benefits. The initial step in treating type 2 diabetes is with metformin. Metformin improves glucose homeostasis by decreasing intestinal glucose absorption, inhibiting hepatic gluconeogenesis, and increasing insulin sensitivity through AMP-activated protein kinase enzyme activation, leading to an increase in peripheral glucose uptake. One of the most popular drugs used to treat type 2 diabetes is acarbose. Acarbose stops increases in PPG following carbohydrate eating because it is an intestinal amylase inhibitor and can compete with small intestine amylases. Dietary fibres can influence absorption and plasma clearance, two processes that determine the bioavailability of orally taken medications [21-24]. Consequently, it is critical to investigate the complex relationship between dietary fibre consumption and the effects of metformin or acarbose on individuals with type 2 diabetes.

Dietary Fiber's Impact on People's Health

Dietary fibre (DF) refers to plant-based foods that remain undigested and indigestible in the small intestine after being fermented in the large intestine. Carbohydrates and their counterparts, such as oligosaccharides, nondigestible polysaccharides, and related plant compounds, make up this total. Based on its solubility in hot water, dietary fibre can be classified as either soluble (SDF) or insoluble (IDF). Noncellulosic polysaccharides that make up SDF include oligosaccharides and occasionally indigestible polysaccharides such as inulin, arabic gum, gum, pectins, galactomannan, and β-glucans. A few hemicelluloses, cellulose, and lignin make up IDF. DF can be found in many different foods, including as fruits, vegetables, cereals, and more. Various fruits and vegetables, including apples, oranges, persimmons, pears, dry beans, cauliflower, carrots, potatoes, and oligosaccharide, contain higher amounts of SDF with high viscosity. Pectin possesses excellent viscosity and absorbability; it is a network of polygalacturonic acid made up of D-galacturonic acid residues connected by α-1,4 glycosidic linkages. Being able to absorb glucose, cholesterol, and heavy metals is one of its properties. The anti-cancer activity and other biological activity properties of pectin are influenced by its complex side chains and varying degrees of polymerisation, as demonstrated by Willats et al., and the mechanism by which this occurs should be investigated. A majority of IDF, including cellulose, lignin, and semi-fibers found in grains (such as wheat, soybeans, mung beans, and oats), possess excellent swelling properties despite their tiny viscosity. The linear molecule known as cellulose is composed of glucose linked by β(1→4) glycosidic linkages and is an insoluble polysaccharide. The stable fluorescence structure formed by hydrogen bonding between neighbouring cellulose chains is what gives cellulose its many useful properties, such as its ability to retain water, swelling water, oil, glucose, cholesterol, and other adsorbents. references [25]. The prevalence of non-communicable diseases, such as obesity, diabetes, cancer, gastrointestinal disorders, and others, is on the rise due to the fast pace of modern society's growth. An increase in global mortality is a direct result of the fact that disease incidence is rising annually [26, 27]. In addition to raising financial burdens on families and nations, the prevalence of chronic diseases has a negative impact on people's level of happiness [13,14]. According to research by Wei et al., the risk of metabolic syndrome is 11% lower for every 10 g/day increase in total fibre consumption. Among the DF, research has shown that fibre from cereals and fruits can lower the likelihood of metabolic syndrome. The physicochemical properties of DF, which vary between structures, are crucial in controlling the human body's health regulation process. Research indicates that DF's physicochemical features—including WHC, WSC, OHC, GAC, CAC, and visibility—are intricately linked to physiological processes. As a result, we go over the physicochemical and physiological connections between these functions, and we compile the DF products used in functional foods. These will likely serve as the groundwork for future DF health food developments.

Dietary fiber (DF) and obesity

Worldwide, the number of people diagnosed as fat has been steadily rising in recent years. From 3.2% in 1975 to 10.8% in 2014, the worldwide prevalence of obesity in males rose, according to data from 200 nations. The numbers also show that the percentage of women has risen, from 6.4% to 14.9%. Over 1.6 billion adults were overweight in 2016, with over 650 million being obese. Additionally, over 340 million children and adolescents between the ages of 5 and 19 were either overweight or obese. An increasing number of people are overweight or obese, which is a problem for people all over the world and a danger to their health [62]. Obesity reduction is a pressing issue that needs immediate attention. There is strong evidence that DF can help prevent obesity if consumed in sufficient amounts. In order to control calorie consumption, DF controls food intake, digestion, absorption, and metabolism, which in turn blocks fat absorption. Here is the major way that DF helps you lose weight: 1) Nutrient movement may be slowed by the high viscosity of SDF, such as gum and gum arabic. Due to its galacturonic acid composition, DF is quite viscous. The fat-enhancing properties of DF are due to its high WHC, OHC, and CAC levels. On top of that, IDF's network architecture allows it to have superior CAC. According to Mandimika et al., broccoli DF lowers blood cholesterol levels because its sticky pectin helps the liver remove cholesterol and bile acid from the bloodstream more efficiently. This, in turn, lowers dietary fat consumption. The high concentration of IDF in the shell of bamboo shoots was discovered by Luo et al. [39] to have the ability to bind or adsorb bile acids and cholesterol, resulting in a decrease in cholesterol in different pools. To improve fullness and decrease food consumption, DF has good water-saturated content (WSC) [28, 29]. Researchers Lambert et al. discovered that DF can delay the absorption of nutrients and successfully reduce energy intake by increasing satiety and water absorption. 3) As it encourages the release of glucagon-like peptide 1 (GLP-1) and YY peptide (PYY), DF also creates SCFAs through intestinal microbial fermentation. Intestinal L-cells secrete GLP-1, which regulates glycogen synthesis in muscle cells, increases satiety, and promotes insulin production and pancreatic cell proliferation. Intestinal secretion hormone PYY has an anti-obesity impact by lowering food intake and decreasing hunger. In a study conducted by Chang et al., it was found that the IDF of pear pomace has the ability to reduce fat cells and ameliorate obesity. This is because it dilutes energy, increases energy consumption, and promotes the production of GLP-1 and PYY following intestinal fermentation. Overall, DF's physicochemical properties—including WHC, WSC, OHC, CAC, and viscosity—delay the absorption of dietary fat, which contributes to its ability to improve obesity. Obesity reduction is a result of both SDF and IDF, but determining which is superior needs more experimental study.

Dietary fiber (DF) and cancer

One of the most prominent societal issues that poses a significant risk to human health is cancer. Thus, cancer prevention must be prioritised. There is a strong correlation between what people eat and their risk of developing cancer; a high DF diet has been shown to successfully ward off several types of cancer (Table 2). The following factors primarily reflect the mechanism of DF to prevent cancer. 1) Intestinal carcinogen concentrations can be reduced, stool volume can be increased, and defecation time can be accelerated thanks to DF's WHC and SWC. Reducing the concentration of carcinogens in the intestinal epithelium, Dahl et al. found that DF can lower the risk of colorectal cancer due to the increased faecal size and slower transit time. 2) DF has the ability to raise excretion and decrease hormone concentrations in the blood. Inhibiting hormone release and reducing hormone bioavailability is the key method for preventing ovarian and breast cancer. Research conducted by Ho et al. demonstrated that DF found in fruits and vegetables can inhibit oestrogen enzymes and reduce oestrogen release, hence preventing female breast cancer. Xu et al. also found that DF consumption lowers steroid hormones and aids in insulin growth factor regulation, which in turn lowers the incidence of ovarian cancer [30, 31]. An ovarian cancer risk reduction of 3% is observed with every 5 g/day increase in DF (relative risk, 0.97; 95% CI, 0.95-0.99). 3) Butyrate and other saturated fatty acids (SCFAs) produced by DF fermentation can increase apoptosis in cancer cells cultivated in vitro by inhibiting histone deacetylase and associated signalling pathways. Kawakita et al. found that DF lowers cancer risk by lowering inflammation and encouraging the creation of SCFAs by gut bacteria that have antiproliferation and pro-apoptotic characteristics.

Problems with the Digestive System and Dietary Fibre (DF)

One of the body's biggest defence mechanisms is the gastrointestinal tract. When gut flora and fauna are in good health, they can influence the mucosal immune system and aid in food digestion. A compromised intestinal barrier, brought on by an imbalance in the gut microbiota, can increase vulnerability to specific diseases. Diet and way of living significantly correlate with the prevalence of gastrointestinal disorders. A healthy gut is the result of a balanced microbiota, regular bowel movements, and a strong intestinal barrier, all of which can be achieved by increasing DF consumption. Beneficial bacteria are essential for illness prevention and treatment, and DF fermentation in vivo can boost their development while limiting that of pathogenic bacteria. Supplementation with Konjaku flour (KF) considerably decreased the weight of obese mice, according to Kang et al. The reason behind this is that in the gut microbiota of mice on a high-fat diet, KF increases the abundance of certain beneficial microbes (like Megasphaeraelsdenii) and decreases the abundance of harmful microbes (like Alistipes, Alloprevotella, Bacteroides acidifaciens, and Parabacteroides goldsteinii) associated with obesity. Furthermore, by controlling the intestinal flora, soybean IDF was able to prevent obesity in mice fed a high-fat diet. A higher population of the pro-obesity

Lactobacillales, Lactobacillus, and Lachnospiraceae NK4A136 bacteria may be associated with soybean IDF consumption. Mice on a high-fat diet had their body weight drastically lowered by the prevalence of Bacteroides acidifaciens. Researchers Zhang et al. found that diabetic rats treated with inulin had an increase in the populations of the probiotic bacteria Lactobacillus, Lachnospiraceae, Phascolarctobacterium, and Bacteroides. A high-DF diet can protect against colon cancer by encouraging the growth of good bacteria, according to research by Faraz et al. Results from the study by Alfa et al. show that resistant starch can alter the relative abundance of butyric acid and the ratio of Firmicutes to Bacteroidetes, as well as ameliorate the gut microbiota of middle-aged and elderly individuals. Functional constipation can be alleviated and gastrointestinal digestion can be improved by DF's good WHC and SWC. In a study conducted by Chao et al., it was demonstrated that combining DF with WHC and SWC can enhance defecation and alleviate symptoms of constipation in children. Esophageal motility and weekly reflux and heartburn episodes in patients with non-erosive GERD are improved by a diet rich in DF. Since DF can both lengthen the intestines and preserve the intestinal barrier, it promotes intestinal health. The integrity of the intestinal barrier can be protected by the SCFAs produced during DF fermentation, which have the ability to suppress inflammatory factors. Research by Chapman et al. found that butyric acid, when administered at higher concentrations, could reduce the symptoms of ulcerative colitis. Reduced mucosal proinflammatory cytokines, as a result of SCFAs produced by inulin in the colon, are associated with less severe mucosal damage and less painful crypt damage. Intestinal Lachnospiraceae quantity is enhanced by consuming cooked pea DF, according to Zohre et al. The protective role of the intestinal mucus layer is aided by higher butyrate production, which in turn enhances the expression of Muc2 and Muc4, the primary components of this layer. An individual's colon length influences the results of DF fermentation; a longer colon allows for faster fermentation and a higher degree of fermentation. According to Dert et al., digestive disorders can cause a decrease in colon length. Soybean IDF can lengthen mice's colons, protect their intestines from the harmful effects of a high-fat diet, and restore normal cell structure and uniformity to the colon epithelium and goblet cells, according to our research.

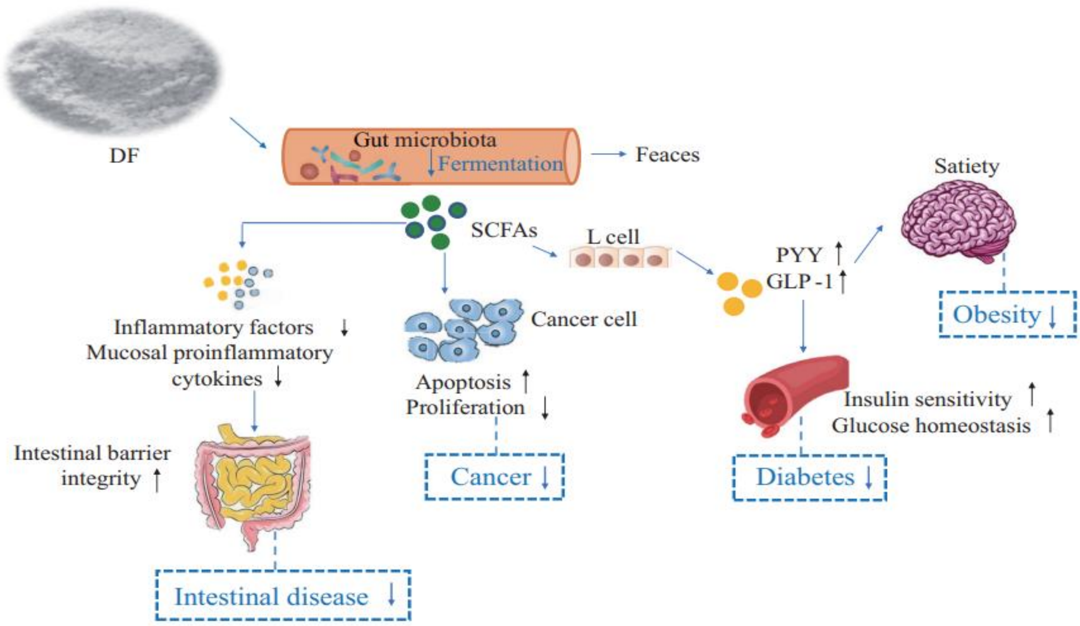

Figure 2.When it comes to disease prevention and therapy, DF and SCFAs go hand in hand.

Diabetes and Glucose Metabolism

The glucose metabolism is mostly affected in the skeletal muscles and liver when insulin secretory capacity is reduced or lost altogether. As a result of decreased glucose uptake by the skeletal tissues, which normally accounts for around 70% of ingested glucose disposal, diabetics experience significantly higher postprandial or postmeal glucose increases. Insulin regulated glucose transporters (GLUT4) are typically activated when blood sugar levels are normal, a condition that does not occur in people with diabetes. While much of the reduced absorption in diabetes is due to poor GLUT4 activation, new research suggests that problems with glucose metabolism once glucose reaches the muscle cell might also play a role. There is less glucose storage as glycogen, according to studies that used nuclear magnetic resonance (NMR) spectroscopic techniques to examine the intracellular glucose flux. Plasma glucose concentrations in the fasting state are primarily determined by the liver's excessive glucose synthesis, which plays a significant role in the diabetic state. The overall health burden of type 2 diabetes is significantly impacted by the maintenance of chronic hyperglycemia. Problems with the eyesight (retinopathy), kidneys (nephropathy), nerves (peripheral and autonomic neuropathy), the gastrointestinal tract (GERD), the urinary system (nephropathy), the heart (cardiovascular disease), and erectile dysfunction (erectile dysfunction) are all directly influenced by hyperglycemia.

Managing Blood Sugar Levels and Lipids

The metabolic dysfunction of carbohydrates metabolism is only one aspect of diabetes. Crucially, atherogenic plasma lipid profiles, marked by lower levels of high-density lipoprotein (HDL) cholesterol and higher concentrations of plasma triglycerides, are typical in type 2 diabetics. While diabetes often does not affect total levels of low-density lipoprotein (LDL) cholesterol, it is associated with an increase in the number of smaller and denser LDL particles. High total cholesterol, triglycerides, and lower HDL levels are the strongest predictors of later coronary heart disease (CHD) in diabetic populations, according to prospective studies [32]. The risk of coronary heart disease (CHD) is two to four times higher in diabetics. The postprandial rise in plasma lipoproteins may also play a significant role in atherosclerosis, according to some writers. Postprandial lipemia is usually protracted and high in diabetics.

Objectives of Diabetes Diet Therapy

When it comes to managing type 2 diabetes, dietary therapy is still crucial. The main focus of dietary therapy for diabetes has been reducing plasma glucose levels while simultaneously increasing the action of insulin. It is evident that glycaemic control helps prevent or delay the onset of retinopathy, nephropathy, and neuropathy in people with type 1 diabetes, also known as insulin-dependent diabetes mellitus (IDDM), as lower plasma glucose levels are achieved with more vigorous and aggressive insulin therapy. Research on the effects of intensive insulin therapy in addition to the standard first-line oral medications and diet for people with type 2 diabetes has focused on glycaemic control. Although extensive insulin treatment can bring blood glucose levels back to normal, it has not been shown to reduce the incidence of vascular or cardiovascular disease. The fact that dyslipidaemia continues even after the aberration in blood glucose control is minimised may be the cause of this seeming paradox. In order for dietary interventions to be effective in managing type 2 diabetes [33], their intended effects on blood glucose and cholesterol levels must be considered. This is in line with the most current ADA guidelines, which identify the five main aims of medical nutrition therapy and represent this viewpoint. The primary goals of this approach are to achieve ideal serum lipids and return blood glucose levels to a normal range. Crucially, people with type 2 diabetes who are undergoing medical treatment through dietary changes must work together as a team, demonstrating the necessity of a multidisciplinary strategy. To maximise adherence and account for cultural, ethnic, and economical constraints, it is important to involve the individual with diabetes in goal setting and prescribing.

Dietary Fiber's Role in Diabetes Management Throughout History

For a long time, the mainstay of diabetes treatment was food restrictions. Unfortunately, conventional wisdom was hindered by a lack of knowledge regarding the interplay between food components and metabolic processes. In the second century a.d., the Greek physician Areaemus proposed a special diet for those with diabetes that included milk with additional cereals, fall fruits and sweet wines. He also invented the term diabetes. Diets that consisted nearly exclusively of meat were among the many bizarre eating plans that were advised throughout the centuries that followed. In 1776, Dobson noticed that diabetics had sweet urine, which was the first clue that diabetes is a disorder of sugar metabolism. Following this finding, two schools of thought emerged; one argued that a sugar-rich diet was best for people with diabetes as the disease was characterised by excessive sugar loss. But the second, more influential school of thought held that carbohydrate restriction was the best course of action because diabetes was a condition of excess production. Up to the groundbreaking discovery of insulin in 1922, doctors still recommended carbohydrate-restricted diets that included frequent fasting. Diabetes care and patient longevity were both enhanced by the discovery and subsequent usage of insulin derived from pigs. Still, people with diabetes often stick to diets that are low in carbs (10-20% of calories) and high in fat (60-80% of calories) out of dread of carbs [34]. There was a lack of attention to the potential dangers of a diabetic diet in increasing the risk of atherosclerosis and the positive effects of a high-carbohydrate diet on insulin action until the research of Stone and Conner compared high-fat and carbohydrate diets. The unexpected outcome was a reduction in insulin needs and plasma cholesterol levels, as well as good tolerance for the high-carbohydrate meals. Subsequently, there were significant shifts in the dietary guidelines for people with diabetes. In 1971, the American Diabetes Association (ADA) suggested that people with diabetes should eat carbs at the same percentage as the general American population. The inability of later research to back the use of high-carbohydrate diets is mirrored in the fact that many diabetes clinics were sluggish to implement these suggestions, according to reports from this time. With the growing body of evidence supporting the health benefits of dietary fibre came the reaffirmation of the 1979 ADA recommendations. The idea that refined flour and sweets, which do not contain any dietary fibre, are the cause of many modern diseases originated with the concept put forth by Dr. Cleave, a naval surgeon from Britain. He proposed that dietary fibre could guard against the development of noncommunicable diseases. Burkitt and Trowell's seminal work in rural Uganda in the 1960s tested the notion that low rates of diabetes and other noncommunicable diseases were associated with high fibre diets. The fact that the number of diabetic cases dropped in England while the country's intake of whole, high-fiber wheat grew during WWII lends credence to this theory. A high-carbohydrate diet that includes dietary fibre was studied for its effects on glucose levels due to the fiber's possible protective role.metabolism in people who already had diabetes.

Carbohydrate and Fibre Metabolic Effects in Diabetes

The effects of several test meals on the insulin and postprandial glucose profiles of diabetics have been extensively documented in various papers. There is another place where you may find an analysis of all these research using test meals. Novel food formulations including extra dietary fibre or plant varieties or strains with higher concentrations of dietary fibre have been the subject of more recent investigations into their effects. Dietary fibres that are soluble, hydrate quickly, and develop viscosity in vitro are the most common to show reduced glycaemic responses. Although variables other than viscosity alone contribute to the consequent glycemia, the ongoing actions of the dietary fibre to elevate the viscosity of the gastrointestinal contents are necessary for the inhibition of glucose digestion and absorption. A more thorough analysis of the food components that could be used to predict blood sugar levels found that the in vitro digestion rate, which tries to replicate the effects in the body, had a limited correlation with the total dietary fibre content of foods and no correlation with soluble fibre. Digestion rate is modulated by complicated interactions between physical and chemical components within food. Food refinement, cooking time, starch structure, moisture, cellulose, and uronic acid content were all found to be important factors (39). A carbohydrate-rich food source's final rate of glucose arrival in the blood stream is determined by a complicated interplay of many components of the food. The glycaemic index (GI) was established to account for this interaction. When comparing the relative glycaemic reactions of different foods or meals, the GI has shown to be a reliable instrument. Foods high in sucrose and other sugars, such as fructose, have been the subject of glycaemic impact studies in tandem with the liberalisation of sucrose intake in diabetic diets. Curiously, the GI of foods high in sucrose was discovered to be similar to that of numerous starchy foods, such as bread and a number of cereal items. Sucrose did in fact reduce the overall glycaemic response of an unsweetened, high-GI morning cereal. Due to its slower absorption and nearly complete elimination from circulation by the liver, fructose—which is sweeter than sucrose—has a lower GI than sucrose. Glucose metabolism remains unchanged when sucrose or fructose is substituted for starch, however one study found that insulin action improved after fructose was substituted for starch. It is crucial to think about how sucrose or fructose would affect plasma lipids. Studies showing either no change or increased plasma triglyceride contents in diabetics have cast doubt on the effects of fructose-rich diets in particular. A study conducted on five patients with NIDDM found that endogenous very-low-density lipoprotein (VLDL) production was unaffected by fructose-rich diets. However, there was a great amount of diversity in the responses that were recorded. Nevertheless, it might be wise to monitor and tailor sugar prescriptions [35] for individuals with NIDDM due to the high degree of heterogeneity in postprandial lipid responses and the observed variability in plasma lipid levels after high-sugar diets in clinical trials.

Mechanisms of Action

It remains a matter of conjecture how slowed carbohydrate absorption might ultimately act toimprove insulin sensitivity in diabetics. To date, four distinct mechanisms have been proposedto account for how meals containing increased amounts of dietary fiber may act to improveglucose metabolism at subsequent meals.a. Inhibition of Fatty Acid Oxidation. One hypothesized mechanism for the subsequentimprovement in insulin action following the ingestion of a slowly digested and absorbedcarbohydrate-rich meal is the inhibitory effect nonesterified fatty acids

(NEFAs) have on glucoseutilization. Elevated NEFA concentrations have been shown to increase fat oxidation rates,which lead to a commensurate reduction in glucose oxidation, a metabolic relationship knownas the glucose–fatty acid cycle, first described by Randle et al. Indeed, the tendency fordiabetics to have elevated plasma NEFA levels may contribute to the impairment of insulinaction. Slowed carbohydrate absorption leads to moderated, although sustained elevations

in plasma glucose paralleled by sustained plasma insulin concentrations. The maintained insulinsecretion may maximize glucose uptake and oxidation by insulin-sensitive tissues while simultaneouslysuppressing lipolysis and NEFA availability, thus lowering fat oxidation. Rapid glucoseabsorption is, however, speculated to rapidly increase plasma insulin concentrations, leading torebound hypoglycemia and the release of counterregulatory hormones, including the catecholamines.Catecholamine release activates lipolysis and increases plasma free fatty acid (FFA)levels. However, there is limited in vivo evidence for this hypothesis. Two studies have

found that, in comparison to an isocaloric low-fat meal, a high-fiber meal led to a more persistent decrease of NEFA levels and fat oxidation [36]. However, there have been studies that have failed to show any changes in substrate oxidation, even when there are large differences in blood glucose absorption profiles. b. Short-Term Decreases in Blood Sugar. The short-term reduction of plasma hyperglycemia and hyperinsulinemia after a meal is another potential effect of delayed carbohydrate digestion on insulin activity. In vitro, acute hyperglycemia quickly decreases insulin receptor tyrosine kinase activity, GLUT4 abundance, and, through gene expression regulation, may dysregulate protein synthesis. "Glucose toxicity" refers to the recognised impairment of insulin secretion and sensitivity caused by chronic hyperglycemia, however there is no proof that immediate postprandial changes mitigate this effect. c. Hormone Secretion in the GI Tract. Several studies have shown that after eating meals high in fibre, the release of some gastrointestinal hormones, such as glucagon-like peptide 1 (GLP-1), somatostatin, vasoactive intestinal polypeptide (VIP), and insulin-like growth factor 1 (IGF-1), changes. The plasma levels, however, vary greatly across trials, and not all of them found changed production of hormones by the gastrointestinal tract. Importantly, GLP-1 and IGF-1 play key roles in controlling insulin secretion and action, but whether altered blood concentrations can suddenly alter insulin action is still up for debate. The potential effects of altered production of these gastrointestinal hormones on glucose and lipid metabolism in diabetics need more investigation. it has been proposed that gums, pectins, and polysaccharides influence lipid and glucose metabolism. The most important nongaseous byproduct of this anaerobic fermentation process is short-chain fatty acids (SCFAs). Specifically, the most abundant products are acetate, propionate, and butyrate, which are generated in around a 60:25:12 molar ratio. The intestinal epithelium quickly absorbs these SCFAs, with large amounts of propionate and acetate entering the portal blood stream. The only SCFA present in peripheral blood at quantities that are considered significant is acetate [37]. A high-fiber diet raises acetate concentrations in the periphery. A single study found that while neither glucose oxidation nor glucose tolerance changed, acetate intake orally and cecal infusion reduced adipose tissue lipolysis and plasma NEFA levels. In ruminants, propionate is a key gluconeogenic precursor that the liver removes from the portal circulation. Propionate may have an inhibitory effect on gluconeogenesis and a stimulatory effect on glycolysis in nonruminants like humans and rats. Although oral glucose tolerance was slightly improved, blood glucose levels were unaffected by the capsule-based oral propionate. Propionate may have inhibited starch digestion, which would explain why adding it to bread enhanced glucose responses. In contrast to prolonged portal release in living organisms, the quick absorption of propionate when taken orally may not be accurate. No effect of propionate on insulin sensitivity or glucose production in the liver has been shown in studies that have used rectal or ileal propionate infusion, which are more representative of the in vivo setting. Another possible function of propionate is to control the amount of cholesterol produced by the liver inboth in vivo and in vitro rodent studies. While physiologically relevant concentrationsof propionate may inhibit cholesterol synthesis in rat hepatocytes, a comparative study has failedto demonstrate inhibition in human hepatocytes, with inhibition of cholesterol synthesis requiringa 100-fold increase in propionate levels. Propionate supplementation in human volunteershas tended to show reduced HDL cholesterol and increased triglyceride concentrations.There is good evidence from a rodent study, in which cecectomized rats were fed a dietcontaining guar gum, that the removal of a cecum does not affect glucose metabolism whencompared to noncecectomized rats. This evidence, combined with the data described above,presents a scenario in which SCFA metabolism is unlikely to significantly affect peripheralcarbohydrate or lipid metabolism in nonruminants.Currently, no clear mechanism has emerged upon which to base dietary strategies to maximizethe effectiveness of high-carbohydrate and high-fiber meals. The lack of an acute mechanismcan be considered as a factor hampering the design of high-fiber diets, which can beconsidered to be most effective in improving both carbohydrate and lipid metabolism in type2 diabetics.

Changes to the Metabolism of Sugar

Few research have developed realistic and acceptable high-fiber diets that are likely to affect postprandial glucose absorption profiles, which is unexpected given the significant evidence collected from studies modifying GI or glucose absorption profiles. Only a small number of dietary programs have really assessed the effects of meals on glucose and insulin levels. There are two main ways of changing one's diet among the dietary interventions that have looked at the effects of a high-fiber diet. The first is to supplement the diet with viscous soluble fibres at a dosage that will slow the absorption of glucose. The second set of research has used dietary fibre dosages that are at least double the recommended daily allowance. Guar gum has been the most commonly used viscous soluble fibre in dietary interventions that have investigated its effects on carbohydrate metabolism; however, pectin, glucomannan, and xanthan gum have also been investigated. Studies have shown that adding guar gum to a high-carbohydrate diet reduces glycosylated haemoglobin and glycosurea and improves insulin sensitivity. But getting enough soluble fibre from food alone isn't easy enough to accomplish these goals. Although guar gum-containing or oat bran-rich food products have shown some benefit in trials, they are still not widely accepted or used as part of diabetes dietary therapy. The insulin action of diabetic participants has been shown to improve in multiple trials; however, the diets used in these studies had dietary fibre amounts ranging from 90 to 45 grammes daily. Only after switching to a high-fiber diet did the favourable effects on insulin sensitivity become apparent, according to the studies that compared matched carbohydrate and fat intake with low and high fibre content, respectively. Research showing that diets containing about 40 g of dietary fibre per day had no influence on insulin activity contradicts these trials. These studies are obviously overly optimistic and do not apply to the larger diabetic community, regardless of the outcome regarding glucose metabolism. The typical daily intake of dietary fibre in developed nations is estimated to be around 10–13 g.

Impact on Biliary Acid Metabolism

Plasma triglyceride levels rise and HDL cholesterol levels fall on high-carbohydrate diets. It is evident that high-carbohydrate meals might worsen postprandial hypertriglyceridemia, mostly because of increased hepatic secretion of VLDL triglycerides, but this is not always the case. These alterations in triglyceride metabolism are often less severe when dietary fibre is included in a high-carbohydrate diet. The vast majority of research has shown that dietary fibre, and especially soluble fibre, can reduce levels of plasma cholesterol and LDL. Monounsaturated fat-rich diets are just as effective as saturated fat-rich diets in reducing plasma lipids and improving atherogenic risk. According to recent research, the best way to improve postprandial plasma lipid profiles is to consume a combination of monounsaturated fatty acids and dietary fibre, which is more like a traditional Mediterranean diet.

Extra Advantages of Diets Rich in Carbohydrates and Fibre for the Control of Diabetes

Although there is some debate about whether or not a high-carbohydrate, high-fiber diet can help with type 2 diabetes glucose and lipid metabolism, there is strong evidence that these diets have other positive effects. A higher amount of dietary fat is positively associated with a higher body mass index, according to epidemiological studies. Despite the fact that carbs and fat are equally filling, eating foods that are heavy in fat will probably make you eat more calories overall. Many studies have shown that when given free reign to eat whatever they want, people tend to choose higher-fat foods because they are more appealing, have better flavour, and are more enjoyable. Nonetheless, research comparing the consumption of fat-only food items reveals that people consume more food based on bulk than on energy content, which results in passive energy overconsumption. There is a significant difference between carbs and fats in terms of storage capacity and metabolic reactions. Glycogen and other forms of stored carbs are little (200–500 g) and humans have a negligible ability to synthesise lipids from glucose and other carbohydrate precursors (de novo lipogenesis). Modulating the rate of glucose oxidation allows one to attain accurate maintenance glycogen levels, even with widely varying daily carbohydrate intake. The body's glycogen stores are replenished when carbohydrates are consumed. Subsequently, the body's glucose oxidation is adjusted to quickly restore total carbohydrate balance.

Humans, in contrast to carbohydrates, have an enormous fat storage capacity, mostly in adipose depots. The primary determinant of fat balance is the disparity between total energy expenditure and the energy consumed as carbs or protein. Fat storage occurs in tandem with increased fat consumption rather than the other way around. Furthermore, there is scant proof that monounsaturated fatty acids are any different from other types of fatty acids when it comes to energy metabolism. By increasing carbohydrate oxidation and total energy expenditure, the group that intentionally consumes more carbohydrates than fat gains less weight (138). However, calorie consumption and weight loss are the results of dietary regimens that attempt to increase carbohydrate intake. Accordingly, it is evident that carbohydrate-rich meals are beneficial for diabetics to maintain adequate weight control. People with diabetes may see an improvement in insulin activity just from cutting calories before they lose weight. Glycaemic control and consequences from diabetes are both significantly improved with sustained weight loss and calorie restriction. Improving insulin action is a primary goal of diabetic care plans that aggressively reduce body weight by gastric restriction surgery or very low calorie diets (VLCDs). Many adults with diabetes prioritise slow weight loss and, more significantly, weight management, even if rigorous weight restriction may be suitable for some. Studies on obese people have shown that a 10% cut in fat calories results in a 4-5 kg weight loss on average. A low-fat, high-carbohydrate diet and regular exercise are the cornerstones of effective post-obese weight management, which is essential for maintaining the weight decrease.

CONCLUSIONS

There is substantial evidence to suggest that people with type 2 diabetes would benefit from a diet low in carbs and high in monounsaturated fatty acids rather than the opposite. This is supported by the existing evidence that suggests selectin-free, high-carbohydrate diets for weight maintenance may have a little negative effect on blood glucose and cholesterol levels. A combination of eating low-GI foods or foods high in dietary fibre and reducing the meal's glycaemic impact may offer some protection, nevertheless. Despite this research, diets that try to include very high levels of dietary fibre are not recommended. A highly motivated individual is likely to be the only one who can successfully adopt a lifestyle that includes much more dietary fibre, although this may have some additional health benefits. When treating type 2 diabetes with nutrition, it is not necessary to pay more attention to the fibre level of the diet than what is suggested for the general population. Optimal, according to the American Losing weight and keeping it off should be top priorities for those with type 2 diabetes. Diets rich in carbohydrates, with a variety of meal planning alternatives, are essential for weight management. Personalised, varied, and long-term dietary regimens with a focus on carbohydrates should continue to be the cornerstone of nutritional therapy for type 2 diabetes. Molecular mechanisms underlying the protective effects of dietary fibres and polysaccharides on hyperglycemia and diabetes remain unclear. We need further research to figure this out. What kinds of foods, especially those high in polysaccharides and dietary fibres, are best for enhancing glucose metabolism? There is another option besides this one. The dietary patterns and food production conditions in each country and/or area will determine the food that is available for selection. On the other hand, DF studies do have few flaws. To start, the polymerisation degree of DF varies from one source to another, which means that it could potentially have a protective impact against varied diseases. Further research on disease prevention is needed to clarify the structure of different polymerisation degrees of DF from different sources, as the impact of these degrees on the disease prevention mechanism is currently unclear. Second, the diseases that DF can prevent are not limited to the ones discussed in this review. There needs to be a lot of experimental study into modulating the gut microbiota for the prevention and treatment of other diseases. Third, the type and amount of DF consumed affects illness prevention and therapy. In order to find out how much of each kind of DF is best for illness prevention and therapy, research into dosage and type (SDF vs. IDF) is required. By resolving these issues, DF will become a better tool for improving people's health and reducing the prevalence of preventable diseases.

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