Role of Dietary Fiber Supplementation in Prevention of Diabetes Mellitus

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Abstract— *Type 2 diabetes mellitus (T2DM) is a common metabolic disease that is frequently associated with obesity and insulin resistance. Dietary fiber greatly improves glycemic control, cholesterol management, and weight regulation, even while drugs are necessary. Because of their solubility, viscosity, and gel-forming qualities, soluble fibers—like psyllium, black cumin, flaxseeds, basil seeds, and guar gum—have a beneficial effect on metabolic health. Based on clinical studies, fiber supplementation improves waist circumference, BMI, and glucose levels in a variety of populations, including individuals with type 2 diabetes, prediabetes, and pregnant women. Reduced incidence of diabetes, fasting glucose, HbA1c, body weight, and cholesterol are highlighted by randomized controlled trials. Viscose and soluble fibers improve metabolic health by delaying the absorption of glucose. One easy and efficient way to avoid diabetes is to incorporate fiber into your diet. The purpose of this study is to assess the therapeutic effectiveness of dietary fiber supplements in the management and prevention of diabetes.*

Keywords— Diabetes, Supplements, Dietary Fiber, Types of Fiber Supplements, Management.

I. INTRODUCTION

Diabetes mellitus (DM), a metabolic disorder, is characterized by persistently high blood sugar levels and variable levels of impairment in the metabolism of proteins, lipids, and carbohydrates. One of the oldest diseases that people have ever encountered is probably diabetes mellitus. It was initially recorded in an Egyptian papyrus approximately 3,000 years ago [1]. In 1936, the distinction between type 1 and type 2 diabetes was made. Type 2 diabetes was first recognized as a component of the metabolic syndrome in 1988 [2]. Diabetes mellitus can have many different causes and origins, but abnormalities in either insulin secretion, response, or both are always present at some point over the course of the disease. The majority of people with diabetes mellitus have either type 1 diabetes (idiopathic or immune-mediated). The most prevalent kind of diabetes mellitus, known as type 2 DM (non-insulin dependent DM), is typified by hyperglycemia, insulin resistance, and relative insulin insufficiency [3]. Genetic, environmental, and behavioral risk factors interact to cause type 2 diabetes [4] [5]. Additionally, genetic problems, various diseases, the hormonal milieu during pregnancy, and some medications can all be linked to diabetes [6]. The inflammatory process that kills beta cells is the characteristic of type 1 diabetes mellitus, sometimes referred to as juvenile diabetes, and usually leads to total insulin insufficiency [7]. Type 1 diabetes is usually indicated by the presence of insulin, islet cell, or anti-glutamic acid decarboxylase antibodies, which identify the autoimmune processes responsible for beta cell loss. To maintain normoglycemia, insulin therapy will eventually be necessary for all patients with type 1 diabetes. There has been and will continue to be debate regarding the relative significance of abnormalities in insulin secretion or the hormone's peripheral activity in the development of type 2 diabetes mellitus. Eighty to ninety percent of all reported cases are Type 2 Diabetes Mellitus. Insulin resistance is intimately linked to intra-abdominal (visceral) obesity, which is seen in most

people with Type 2 diabetes. These people also frequently have dyslipidemia (high triglyceride and low HDL cholesterol; postprandial hyperlipidemia) and hypertension. Furthermore, women who develop diabetes mellitus during pregnancy are identified by an operational classification known as gestational diabetes mellitus, rather than a pathophysiologic disease. Gestational Diabetes Mellitus (GDM) is the term used to describe women who acquire Type 1 diabetes mellitus during pregnancy as well as women who have undetected asymptomatic Type 2 diabetes mellitus that is identified during pregnancy. The third trimester of pregnancy is when GDM typically first appears in women."Other Specific Types" is a classification that includes diabetes mellitus types with a variety of known etiologies. This group, known as Maturity-Onset Diabetes in Youth (MODY), comprises less than 10% of cases of diabetes mellitus and includes people with genetic defects of beta-cell function or insulin action, exocrine pancreatic diseases like pancreatitis or cystic fibrosis, people with dysfunction linked to other endocrinopathies (like acromegaly), and people with pancreatic dysfunction brought on by drugs, chemicals, or infections.

A nutritional supplement designed to supply nutrients that may be lacking or insufficiently taken in a person's diet, such as vitamins, minerals, fiber, fatty acids, amino acids, and probiotics. There are several kinds of dietary supplements, but the most popular kind is for vitamins and minerals. They can be obtained as single nutrients or as a blend of many micronutrients [8]. The Institute of Medicine (IOM) defines fiber supplements in the United States as a subcategory of effective dietary fiber. Supplements containing fiber come in powder, pill, and capsule form. Dietary supplements used by bodybuilders and athletes are known as bodybuilding supplements. These can be taken in place of meals, to help you gain weight, lose weight, or perform better in sports. Overall, the most utilized substances are glutamine, essential fatty acids, meal replacements, creatine, weight reduction products, and testosterone boosters.

The complex chronic metabolic disease known as type 2 diabetes mellitus (T2DM) is typified by dysregulation of the metabolism of macronutrients, including fat, protein, and carbohydrates, which is brought on by insulin resistance or decreased insulin production [9]. Even though the standard clinical treatment for type 2 diabetes involves taking anti-diabetic medications orally, insulin therapy is eventually required because of the gradual decline in β-cell capacity [10]. One of the most reliable and secure methods of regulating blood sugar levels is still dietary treatments, sometimes referred to as "Medical Nutrition Therapy" [11]. The therapeutic benefits of dietary fiber, which is neither absorbed nor digested in the human small intestine and is strongly linked to gut hormone and gut microbiota, are one of the most researched dietary patterns [12]. Particularly with regard to the connection to type 2 diabetes. Viscous β-glucan is an example of soluble fiber that might positively impact short-term gut hormone responses, insulin, glucose, and satiety [13]. However, insoluble fiber is typically poorly fermented and may have an impact on human health through the gut microbiota and its byproducts [14]. Indeed, consumption of dietary fiber has been confirmed to be inversely related to the progression of type 2 diabetes [15] and can flatten glycemic and insulinemic responses [16]. However, there have been mixed results about the effects of dietary fiber in reducing glycated hemoglobin (HbA 1c), varying by the type and dose of fiber, with only soluble fiber being fully explored [17]. In addition, due to minor side effects like diarrhea, bloating in the abdomen, and flatulence, no meta-analysis evidence was found to clarify the negative effects of fiber with respect to a specific dose [18]. Therefore, the present study aims to provide clinical efficacy of dietary fiber supplementation in prevention of Diabetes Mellitus.

II. MANAGEMENT OF DIABETES

One of the biggest challenges facing healthcare professionals today is managing the continuing needs and expectations of individuals with chronic diseases like diabetes [19]. For those with diabetes, routine follow-up visits with the doctor are essential to avoiding long-term effects. Studies have demonstrated that strict metabolic control can prevent or delay the onset of diabetes-related issues [20] [21]. Large, randomized trials including patients with type 1 diabetes or newly diagnosed or established type 2 diabetes have shown that controlling glycemia delays the onset and slows the progression of microvascular issues, including retinopathy, neuropathy, and nephropathy [22] [23]. In addition to maintaining proper glucose control, diabetic patients also require rehabilitation, disability limitation, and the prevention of complications. Due to the public's low health literacy and negative attitude toward the illness, some Indian studies found extremely low adherence to treatment plans [24] [25]. Psychosocial constraint is one factor that should be considered when establishing glycemic objectives [26]. Patients with "hypoglycemia unawareness" should have their glucose goals lowered for extended periods of time as they wait for the condition to possibly reverse [27] [28]. The objective is to prevent non-ketonic hyperosmolar coma, infections, water and electrolyte loss, and clinically significant glycosuria in patients with serious coexisting illnesses that might make the treatment strategy difficult. Insulin is recommended for people with type 1 or type 2 diabetes who have insulinopenia whose

hyperglycemia does not improve with diet treatment alone or in conjunction with oral hypoglycemic medications [29]. The most successful blood glucose-lowering treatment may be insulin-assisted blood glucose control [30]. Insulin treatment will eventually be necessary for many type 2 diabetic patients. Insulin needs can surpass 1 unit/kg/day because type 2 diabetes is linked to insulin resistance [31]

III. BENEFITS OF DIETARY FIBER SUPPLEMENTS ON HEALTH

Four main aspects influence clinical efficacy of fiber supplements: solubility, degree/rate of fermentation, viscosity, and gel formation. A fiber supplement's solubility determines whether it will dissolve in water (soluble) or stay as distinct insoluble particles [32] [33]. The four therapeutically relevant parameters listed below can be used to classify fiber supplements: Insoluble fiber (e.g., wheat bran): Does not dissolve or gel; low fermentation; coarse particles provide a laxative effect via mechanical gut stimulation. Soluble, non-viscous, readily fermented fiber (e.g., inulin): Dissolves but does not form gel; rapidly fermented, producing gas and calories; lacks laxative or gel-related benefits; may affect gut microbiota but with no proven clinical benefits. Soluble, viscous, gel-forming fiber (e.g., oats): Dissolves, forms gel, slows nutrient absorption, improves glycemic control, lowers cholesterol; loses gel properties during fermentation, offering no laxative or diarrhea attenuation effects. Non-fermented, viscous gel-forming fiber (e.g., psyllium): Dissolves, forms gel, slows nutrient absorption, improves glycemic control, lowers cholesterol; remains gelled in the bowel, normalizing stool consistency by softening constipation and firming diarrhea. There are various dietary fiber supplements available on the market, including Psyllium husk, Black cumin seeds, Flax seeds, Basil seeds, Guar Gum, Chia seeds and etc.

3.1 Psyllium husk:

It belongs to the kingdom Plantae, genus Plantago Family Plantaginaceae, Species Plantago ovata. The species is renowned for its seeds, which are widely used for their medicinal and dietary fiber benefits. Seeds are used commercially to make mucilage, are commonly referred to as psyllium. Psyllium supplementation for three weeks or more may reduce blood glucose levels in individuals with type 2 diabetes and lower blood cholesterol levels in those with increased cholesterol [34] [35]. Psyllium has been used to thicken frozen delicacies like ice cream. The binding characteristics of psyllium mucilage at a weight/volume ratio of 1.5% are better than those of starch mucilage at a weight/volume ratio of 10% [36]. Psyllium husk is a very viscous soluble fiber that lowers low-density lipoprotein cholesterol and stabilizes blood sugar levels. "Psyllium husk may reduce the risk of type 2 diabetes, although the FDA has concluded that there is very little scientific evidence for this claim [37]

3.2 Black cumin seeds:

It belongs to the species Nigella sativa and Elwendia persica, two quite distinct plants that are both used as spices, can be referred to as black cumin belongs to the Genus Nigella, Family Ranunculaceae, Kingdom Plantae. Numerous medicinal qualities, such as antioxidant, anti-inflammatory, immunomodulatory, anticancer, neuroprotective, antimicrobial, antihypertensive, cardioprotective, antidiabetic, gastroprotective, nephroprotective, and hepatoprotective qualities, are largely responsible for the traditional uses of N. sativa seeds [38]. Thymoquinone, one of the key bioactive substances that was shown to have a protective effect against diabetes, is primarily responsible for the therapeutic actions of NS [39]

3.3 Flax seeds:

It is commonly known as linseed or common flax, is a flowering plant that belongs to the Linaceae family. A half ounce of flaxseed provides 20 to 25 percent of daily fiber needs, making it the richest plant lignan source [40]. It has been demonstrated to be helpful in decreasing blood glucose, cholesterol, weight, and acting as a laxative. It includes both soluble and insoluble fibers. It has been demonstrated that the insoluble fiber in flax seeds slows down the blood's sugar release, which significantly lowers blood glucose levels [41]

3.4 Basil seeds:

It is referred to by the generic term *Ocimum basilicum* or *Ocimum tenuiflorum*, also known as *Ocimum sanctum*, and belongs to the Lamiaceae family. These seeds are typically tiny, black, and after 15 minutes of soaking in water, they take on the consistency of gel and have a mild, nutty flavor [42]. Phytochemicals found in basil seeds have a variety of uses. Rich in fiber, basil seeds lower cholesterol and sugar levels, relieve constipation, and aid in weight loss [43]. Basil seeds prevent blood sugar

spikes by postponing the conversion of carbohydrates to glucose. Another advantage of their high fiber content is improved glycemic management.

FIGURE 1: Types of dietary fiber supplements

3.5 Guar Gum:

Guar gum, often referred to as guaran, is a galactomannan polysaccharide that is extracted from guar beans and has thickening and stabilizing properties that make it suitable for usage in feed, food, and industrial settings [44]. Guar gum is produced from the seeds of the drought-tolerant plant Cyamopsis tetragonoloba, a member of the Leguminosae family [45]. It has been demonstrated that the gel-forming properties of guar gum lower cholesterol and blood sugar. In addition to lowering blood glucose levels, its gelling properties help people lose weight and avoid obesity. Furthermore, the gel-forming properties of guar gum soluble fiber cause the stomach to empty more slowly, which promotes fullness [46].

3.6 Chia seeds:

Chia seeds are edible seeds from the flowering plant *Salvia hispanica*, which belongs to the Lamiaceae family of mints. They aid in weight control by reducing obesity and helping to manage Type 2 diabetes. Chia seeds are high in soluble dietary fats, omega-3 and omega-6 polyunsaturated fatty acids, and other nutrients.

IV. CLINICAL STUDIES ON PREVENTION OF DIABETES THROUGH DIETARY FIBER

Studies have demonstrated the therapeutic benefits of high-fiber diets in the treatment of diabetes. This is because the soluble fiber content slows down the small intestine's absorption of glucose, which may help avoid the blood glucose increase that occurs after a meal or snack [47]. In diabetic patients, fiber consumption has been linked to improved insulin sensitivity and decreased postprandial glucose levels. Soluble fiber's gelling and/or viscous qualities were blamed for these effects [48]

Ruixue Li et al. (2024) conducted study on long-term clinical efficacy of dietary fiber supplementation in middle-aged and elderly prediabetic patients. This study evaluated the long term benefits of DF supplementation on body composition, glucose-lipid metabolism, and clinical regression in middle-aged and elderly patients with prediabetes. In this study Participants were randomized into a control group receiving health education and an intervention group consuming DF supplement daily before meals (15 g of mixed fiber per serving) for 6 consecutive months based on health education. Follow-up was 1 year with a 6-month cycle. Blood and anthropometric parameters were assessed at baseline and 6 months and 12months of follow-up. Fifty-four participants were included in the study, 27 in each group. After 6 months, waist circumference, waist-to-hip ratio, fasting plasma glucose (FPG), 2-hour plasma glucose (2h PG), and postprandial insulin levels were significantly lower in the intervention group compared to baseline. FPG, 2h PG, glycosylated hemoglobin, triglyceride/high-density lipoprotein cholesterol values and diabetes incidence were lower than in the control group. After 12 months, blood glucose and diabetes incidence remained lower in the intervention group. DF supplementation can reduce the degree of central obesity, the levels of FPG and 2h PG, and the incidence of diabetes in middle-aged and older patients with prediabetes.

Caroline Honsek et al. (2018) study conducted on fibre supplementation for the prevention of type 2 diabetes and improvement of glucose metabolism. A modified version of the one-year Prevention of Diabetes Self-management (PREDIAS) lifestyle training program was administered to 180 people with impaired glucose tolerance. Individuals with impaired glucose tolerance were given 7.5 grams of insoluble fiber twice daily for a duration of two years. The study, a randomized controlled trial, found a significant reduction in 2-hour OGTT (Oral Glucose Tolerance Test) levels in both the fiber and placebo groups. However, there was no significant difference observed between the two groups.

Dong-Yao Zhang et al. (2022) conducted study on preventing gestational diabetes mellitus in women who were overweight or obese before to pregnancy by dietary fiber supplements. Randomized controlled trial was conducted in Shanghai General Hospital from June 2021 to March 2022. Women with pre-pregnancy overweight or obesity were given 12 grams of dietary fiber twice daily from 20 to 24+6 gestational weeks. The study observed a reduction in the incidence of gestational diabetes mellitus (GDM), fasting plasma glucose, body weight gain, and preterm birth. However, there was an increase in triglycerides (TG) and the TG/HDL-C ratio.

Ayman S et al. (2018) conducted study on the Effect of Soluble Fiber Supplementation on Metabolic Syndrome Profile among Newly Diagnosed Type 2 Diabetes Patients. The study aims to determine role of soluble dietary fiber supplementation improve Metabolic syndrome profile for 8 weeks of intervention in newly diagnosed type 2 diabetes (T2D) adult patients. This study utilized an experimental design, called clinical randomized controlled trial. The study reported significant reductions in fasting blood sugar (FBS), triglycerides, total cholesterol, systolic and diastolic blood pressure, as well as waist circumference.

Abutair et al. (2016) conducted study on soluble fibers from psyllium improve glycemic response and body weight among diabetes type 2 patients (randomized control trial) : Forty type 2 diabetes patients, non-smoker, aged >35 years were stratified to different strata according to sex, age, body mass index (BMI) and fasting blood sugar level (FBS) and randomly assigned into two groups. Type 2 diabetes patients consumed 10.5 grams of soluble fiber daily for 8 weeks. The study demonstrated significant reductions in BMI, fasting blood sugar (FBS), HbA1c, insulin levels, C-peptide, and HOMA-IR, along with improvements in HOMA-β%.

V. CONCLUSION

Chronic type 2 diabetes mellitus (T2DM) is characterized by insulin resistance and hyperglycemia and is associated with lifestyle variables such as obesity, poor food, and inactivity. Although drugs are still essential, dietary fiber supplements have demonstrated potential for enhancing metabolic regulation. Frequent consumption of fiber improves lipid profiles, lowers insulin, and lowers fasting and postprandial blood glucose, HbA1c. Although longer-term effects require further research, clinical trials indicate fiber lowers the risk of diabetes and helps regulate blood sugar. An all-encompassing strategy that incorporates medication, dietary changes, and lifestyle adjustments enhances long-term health outcomes and efficiently supports diabetes control.

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