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Review Article

Glucose- "The Culprit" and Cholesterol- "The Victim." Balanced Diet with Healthy Lifestyle is the only Solution to Prevent Metabolic Syndrome

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Abstract

From an evolutionary point of view, our nutrition and gut health are accustomed to our environment. There is a well-marked difference in dietary habits specific to a region. These dietary habits vary from region to region. Due to technological advancements and the cosmopolitan development of cities, everything is just a tap away. The evolution of technology has surpassed the evolution of our bodies. In nature, organisms evolve with the evolution of their surroundings at the same pace, and the balance is maintained. sugar or carbs are the most consumed food, have higher cravings, and are easily digested. The fact is never denied that whatever type of food we consume, carbs, fat, or protein should ultimately get converted to an instant energy molecule to utilize instantly. Yet another accepted fact is that excess glucose is stored as fat in the body. Glucose can form both cholesterol and triglycerides. Cholesterol is essential for the production of vitamin D, hormones, and bile acids. Triglycerides are a storage form of fat. The excess glucose is converted to fatty acids. These fatty acids are further converted to cholesterol or triglycerides, a common precursor being acetyl CoA. The amount of glucose that is converted to cholesterol or triglycerides depends on several factors, including the person's diet, exercise habits, and genetics. Many studies are taken up to understand the link between glucose and lipid metabolism even at molecular level but still this field of research is unsuccessful. It is a complex pathway hence, its mechanism remains obscure. The common conclusion derived from various research studies related glucose is that high glucose will contribute for fat synthesis and excess fats cause insulin resistance and β- cell dysfunction and has the same effect exclusively with high fat content too. One can derive the conclusion that hypertriglyceridemia is not just a complication but also a cause of abnormal glucose metabolism. Glucose is indispensable for the body functions and moderation (self-restraint) is the only remedy to avoid its potential toxic effects.

Keywords: Glucose; Cholesterol; Healthy Lifestyle; Metabolic Syndrome

Introduction

From an evolutionary point of view, our nutrition and gut health are accustomed to our environment. There is a well-marked difference in dietary habits specific to a region. These dietary habits vary from region to region. They are also different in different demographics and religions the population follows. A sect of a population having a common dietary pattern also has almost stains of microorganisms in their gut biome because specific types of bacteria are nurtured to the specific type of food that is ingested, accordingly. Due to technological advancements and the cosmopolitan development of cities, everything is just a tap away. The evolution of technology has surpassed the evolution of our bodies. In nature, organisms evolve with the evolution of their surroundings at the same pace, and the balance is maintained. Food is mass-produced in industries with very little human labour and is available at cheaper costs. A wide range of preservatives are added to increase the shelf life of the product, food is highly processed and is stripped of natural flavour and is added with artificial flavours and nutrients. Put apart sugar or carbs are the most consumed food, have higher cravings, and are easily digested. The fact is never denied that whatever type of food we consume, carbs, fat, or protein should ultimately get converted to an instant energy molecule to utilize instantly. Yet another accepted fact is that excess glucose is stored as fat in the body. The common population is always under the impression that fatty food is unhealthy for our heart and body but lacks the concept of the fate of high glucose or carbs consumption. The present article attempts to explain the facts about glucose and clear the myth about cholesterol.

Dietary carbohydrates

Dietary carbohydrates are the body's main energy source, contributing 60-70% of the total caloric requirement. Carbohydrates are grouped under two categories: Carbs used by the body such as starch, glucose, lactose, glycogen, sucrose, and fructose and the carbohydrates not used by the body like cellulose, hemicellulose, pectin, and gums.

The tempting list of foods rich in carbohydrates include rice, grains, potatoes, tubers, noodles, pasta, yummy candies, syrups, sweet beverages, fruits like banana, mangoes, berries, melons etc.

Functions of carbohydrates

Being a major constituent of diet, Carbohydrates play a vital role in the body. They are the main source of energy, providing 60–80% of the body's caloric requirements. They spare proteins from being used for energy, which is important for growth and development. The brain and other parts of the central nervous system are directly dependent on glucose for energy, so a lack of carbohydrates can lead to brain damage. They are also required to oxidize fat and synthesize pentoses, considered as the building blocks of nucleic acids and coenzymes. Non-digestible carbohydrates are important for improving bowel motility, preventing constipation, lowering cholesterol absorption, and improving glucose tolerance [1].

Glycemic index (GI)

The glycemic index is a measure of how quick a food raises the blood sugar levels. Foods that have high GI are digested and absorbed quickly, causing a rapid increase in blood sugar levels, while, foods with low GI are digested and absorbed slowly, causing a gradual rise. The GI of a food is affected by its carbohydrate content, type of carbohydrate, fiber, fat, and protein content. Complex carbohydrates like starch have a lower GI than simple carbohydrates like glucose. However, the nutritional importance of the GI is controversial. Studies have shown that a low-GI diet can help in having good control of blood sugar levels in people with diabetes, thereby reducing the risk of heart disease. Foods with low GI, such as whole grains, fruits, and vegetables are generally recommended by Nutritionists. These foods are low in GI and high in vitamins, minerals, fiber, and other nutrients [2].

Glucose Homeostasis: it is maintained by 3 physiological pathways which include secretion of insulin, glucose uptake at the tissue level and hepatic production of glucose. Thus, it ensures for a constant supply of glucose as energy source to the cells and also maintains constant levels of glucose in blood. Glucose homeostasis is a balance between its intake which includes gut absorption, utilization by tissues includes hexose monophosphate shunt pathway, glycolysis, citric acid cycle activity, glycogen metabolism and endogenous production include, gluconeogenesis and glycogenolysis [3]. Glucose homeostasis is achieved by insulin an anabolic hormone which has a primary control and to some extend it is also achieved by insulin-like growth factors [4]. On the other hand, there are counter regulatory hormones also known as anti-insulin hormones include various catabolic hormones like catecholamines, glucagon, growth hormone, adrenocorticotropic and cortisol- they antagonize the action of hormone insulin [5].

They are many reasons for Insulin resistance one such factor is stress. Severe stress was learnt to reduce insulin secretion and

insulin resistance by enhancing the anti-insulin hormones secretion resulting in the increase stimulation of glucogenesis in liver, catabolism of protein in skeletal muscle and lipolysis in adipose tissues, is known as surgical diabetes [6]. It incurs hyperglycemia in non-diabetes condition. This response is the result of stress by neuroendocrine system. Diabetic population is known to be more susceptible to develop stress further, can develop exacerbation of diabetes contributing to the increase in frequency of complications.

Keto diet

The Keto diet has gained popularity in recent years. It has a very low carbohydrate content with high fat and moderate protein aimed to cause rapid weight loss. Recent studies have found that the keto diet controls glycosylated levels (HbA1C) in populations with type 2 diabetes. It should be noted that it can also cause a significant increase in low-density lipoprotein (LDL) cholesterol levels [7]. The Keto diet has been a popular choice among those who want to lose weight During the Diet, body enters the catabolic state when it is deprived of its primary energy source, carbohydrates, and then it starts breaking down to generate energy. This process produces ketone bodies, which act as an alternative source of fuel for the brain and other organs. Majorly ketone bodies are produced from fatty acids in the liver. They can also be synthesized in the body from amino acids like alanine and glutamine lactic acid, and glycerol. Ketone bodies produce ATPs more efficiently than glucose thus allowing the body to maintain efficient fuel production even during a caloric deficit. However, the keto diet comes with some long-term risks like hepatosteatosis, hypoproteinemia, kidney stones, and vitamin and mineral deficiencies. The ketogenic diet is more effective for weight loss than low-fat diets because it helps to preserve lean muscle mass. It also has several other health benefits, including improved blood sugar control and reduced risk of heart disease. The ketogenic diet limits carbohydrates to 20-50 grams/day, which is a very low amount of sugar.

Low carb ketogenic diet

Blood Glucose control is improved due to less glucose intake and improved insulin sensitivity. In addition to this, low-carb diets may also help in improving blood pressure, blood glucose regulation, triglycerides, and HDL cholesterol levels. However, LDL cholesterol may increase on this diet. The ketogenic diet has also shown promising results in a various neurological disorders, like epilepsy, dementia, ALS, traumatic brain injury, cancers, metabolic disorders, and acne [8]. The ketogenic diet causes favourable biomarker changes, such as a reduction in serum hemoglobin A1c in patients with Type 2 diabetes mellitus [9].

Types of fat

The body has three types of fat cells: white, brown, and beige. White fat cells store energy, brown fat cells generate heat, and beige fat cells can do both. Fat cells can be stored in three ways: essential fat is necessary for health, subcutaneous fat is found under the skin, and visceral fat is found in the abdomen. A high-protein diet combined with regular exercise is particularly effective in preventing storage of visceral fat. Increased visceral fat contributes to the high risk of many serious health conditions including diabetes, heart disease, stroke, breast cancer, colorectal cancer, and Alzheimer's disease. It increases insulin resistance. It is also found that Visceral Fat can raise blood pressure.

Several ways are in practice to reduce visceral fat, like eating a healthy diet, regular exercise, managing weight, quitting smoking, and managing stress, in short, leading a healthy and disciplined lifestyle may balance the visceral fat content in our body [10].

Glucose forms cholesterol or triglycerides?

Glucose can form both cholesterol and triglycerides. Cholesterol is essential for the production of vitamin D, hormones, and bile acids. Triglycerides are a storage form of fat. The excess glucose is converted to fatty acids. These fatty acids are further converted to cholesterol or triglycerides, a common precursor being acetyl CoA. The amount of glucose that is converted to cholesterol or triglycerides depends on several factors, including the person's diet, exercise habits, and genetics. For instance, a diet high in saturated and trans fats increases the risk of high cholesterol levels. On the other hand, a diet rich in simple carbohydrates, such as sugars, can increase the risk of high triglyceride levels.

How to get rid of stored Fat?

Humans have evolved to survive in environments with limited food resources. However, today, most humans have access to an abundance of food, especially foods that are high in fat and amino acids. This excess of nutrients can lead to several health problems, including obesity, diabetes, and heart diseases. One of the main problems with excess nutrients is that our bodies are not very good at getting rid of them. We have evolved to store excess nutrients as fat, which leads to weight gain and obesity. We also have a hard time breaking down excess amino acids, which leads to kidney problems. In addition, the abundance of food has led to a decline in physical activity. Our bodies are not used to processing large amounts of food without burning it off through exercise. This can lead to a build-up of fat and other unhealthy substances in the

body. Research suggests that carbohydrate and nitrogen disposal are two of the most important factors in determining how our bodies handle excess nutrients [11].

The ketogenic diet is a promising treatment for diabetes. It has been known to lower blood sugar levels, correct insulin sensitivity, and even reduce the need for medication in people with type 2 diabetes. In people with type 1 diabetes, the ketogenic diet can help to improve glycemic control and reduce the risk of diabetic ketoacidosis [12]. Studies have shown that following a Mediterranean diet is beneficial in preventing metabolic syndromes. The diet is rich in fruits, vegetables, whole grains, lean protein, and healthy fats with low saturated and trans fat content [13]. Some studies stated that, consumption of fat diet has its impact on depression and adds up to cause anxiety but had not emphasized whether or not diet low in fat will revert back the condition [14].

Understanding the role of carbs in fat synthesis

Few researchers studied the role of sugars in cholesterol synthesis in healthy and diabetic rats, by providing glucose or fructose to their diet. A significant decrease was found in the synthesis of liver cholesterol in rats when fed with 25% glucose or fructose for about 21 days. However, only fructose had this effect in diabetic rats. Surprisingly they found no significant effect in cholesterol synthesis both in healthy and diabetic rats, on the addition of simple sugars to their diet. Even when the researchers changed the diet, diabetic rats continued to have higher cholesterol synthesis in their small intestines. Further studies showed that feeding rats a diet that was 10% fructose reduced liver cholesterol synthesis in both healthy and diabetic rats. Further, it was noticed that just, 2 days of fructose supplementation to the diet is enough to cause this effect of reducing the synthesis of cholesterol. This effect is hypothesized that on consumption of fructose leads to the reduced activity of an enzyme called HMG-CoA reductase in the liver without affecting the concentration of the enzyme. The effect was the same in both healthy and diabetic rats. Finally, the researchers found that intestinal hypertrophy and increased cholesterol synthesis in the intestines, which are both characteristic of streptozotocin-induced diabetes, occurs when either glucose or fructose was the sole source of calories [15].

To investigate the effects of dietary cholesterol on lipids and diabetes, researchers used hamsters that had been fed a diet that caused them to become insulin-resistant and have dyslipidemia. This is achieved by supplementation of the diet high in fructose (40%), fat (30%), and cholesterol (0.05-0.25%) termed FFC (Fat Fructose Cholesterol). These resulted in insulin resistance, glucose intolerance, hypertriglyceridemic, and hypercholesterolemic in hamsters even with the short-term administration of the FFC diet. The effect was more serious when the FFC diet was fed for a longer period from 6 to 22 weeks. It was noticed that the hamsters had developed severe hepatic steatosis, glucose intolerance, and mild increases in fasting blood glucose, suggesting the development of type 2 diabetes, but they also noticed that their beta cells were functioning. The study explained that the metabolic changes are due to a high fructose and fat diet, and higher concentration of cholesterol leads to dyslipidemia and also insulin resistance, resulting in a significant increase in hepatic triglycerides levels in plasma. This is justified stating that hamsters when fed with a high FCC diet caused about 10-15 folds of increase in the levels of hepatic stearoyl CoA desaturase compared to the diet fed with fructose and fat (FF). Thus, the study emphasized the importance of nutrient-nutrient interaction i.e., the interaction of fructose with cholesterol and fat wherein, the concentration of dietary cholesterol is implicated as a major contributing factor for the grade of severity in dyslipidemia and insulin resistance. Prolonged feeding showed higher fasting blood glucose levels suggesting Type-2 diabetes and accumulation of large amounts of cholesterol esters in the liver leading to hepatic steatosis. Such elaborative details are extracted from various studies for instance, a study by Fungwe., *et al.* (the 1990s) stated that dietary cholesterol induces hypertriglyceridemia and increased secretion of VLDL (very low-density lipoprotein), this lipogenic effect is secondary to de novo lipogenesis and decreased fatty acid oxidation. Deng., *et al.* learned that the combination of fructose with a cholesterol diet in rats induces dyslipidemia along with cardiac insulin resistance. All the mentioned studies demonstrated the role of cholesterol in the development of metabolic syndrome. The underlying mechanism is the occurrence of dephosphorylation thereby leading to the inactivation of IRβ subunits (decreases both IRS-1 and 2). Undoubtably diet high in fructose alone can induce higher secretion of hepatic TG can lead to insulin resistance and does not affect the levels of fasting plasma glucose and TG. However, the results were contradictory when fructose was given along with Fat and cholesterol which led to more severity in increasing the levels of insulin and TG in plasma [16]. Researchers wanted to understand how diabetes leads to increased cholesterol synthesis in the small intestine. It is known that limiting food intake prevents increase in intestinal cholesterol synthesis. So they thought that hyperphagia with uncontrolled diabetes leads to increased cholesterol synthesis. They observed that in third-trimester pregnant animals, lactating animals, obese

animals, and animals infused intragastrically with 16 g glucose/day vs. 8 g glucose/day, an increase in food intake is associated with an increase in small intestinal cholesterol synthesis. They concluded that hyperphagia is the chief stimulus in the small intestine of diabetic animals to cause an increase in cholesterol synthesis.

Figure 1: Effect of high carbohydrate diet.

More studies have shown that cholesterol synthesis doesn't increase just by increasing the bulk of food intake. In animals in whom thiry fistulas were surgically constructed, they observed that cholesterol synthesis is increased in the diabetic animals in both the segment of the small intestine stating that excess glucose will also stimulates fat synthesis. Those that were in contact with the food stream and also in those segments of the small intestine that were excluded from the contact. This study suggests that direct contact of the intestinal mucosa is not necessary [17]. A combination of a high-cholesterol diet and high glucose exposure induces a rapid onset of vascular complications in zebrafish similar to the early atherosclerotic vascular injuries in mammalian diabetic models, suggesting that zebrafish may be used as a novel animal model for diabetic vasculopathy [18].

Glucose homeostasis guarantees for continuous supply of energy to entire cells of the body. It ensures the protection of the body from hyperglycemic -induced damages like vascular and neuron cells damage and also protects against the hypoglycemic shock, as glucose uptake is an intermittent process wherein consumption remains a continual process. Glucose homeostatis is controlled by a well-established complex regulatory network which includes both hormonal and neural networks. It plays a crucial role in glucose regulation which include intake, absorption, storage, conversion and finally glucose uptake or consumption. These regulatory mechanism is well organized by pancreatic hormonal located in the central position (islet cells) and are assisted by adipocytes and hormones from gastrointestinal enteroendocrine cells (EECs) [19-21]. Free fatty acids (FFAs) are major substrates and its metabolism is interwined with glucose to enable the energy supply. Depending upon the saturation and length of FFAs, will implicate different regulatory effects on the glucose metabolism [18]. It is established that through β-oxidation FFA will get converted to acetyl CoA thus, links glucose metabolism with citric acid cycle in mitochondria. In-depth research had disclosed that FFAs will also function as the extracellular ligands and activate the G-protein-coupled receptors (GPCR) in the plasma membrane. Various FFA receptors are identified, they are GPR40, GPR41, GPR4, GPR84 and GPR120. It is learnt that they are differently activated by short, medium and long-chain FFAs [22-24]. FFAs explicit integrated effects on glucose homeostasis at the level of endocrine system through the interactions of gastrointestinal-pancreatic-adipocyte (G-P-A).

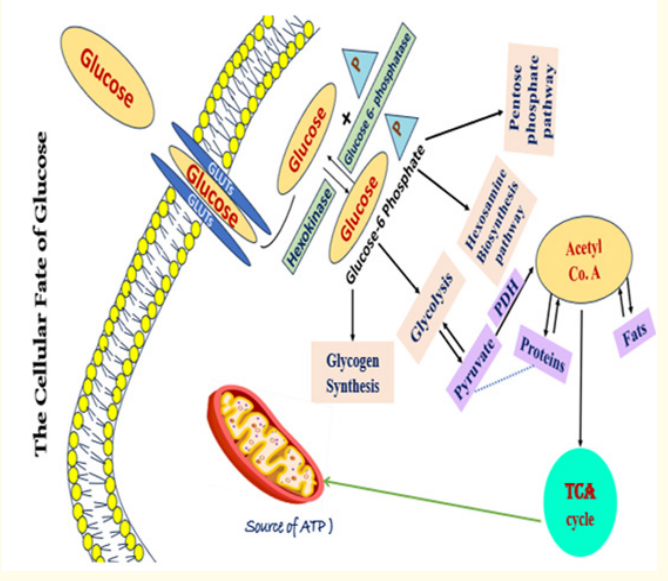

Figure 2: Fate of Glucose2.

It is known that glucose, triglycerides, lipoproteins, fatty acid and insulin interwine, intersect and are linked at various metabolic pathways in various tissues. Glucose and lipids being the source of energy and both metabolic pathways are regulated by liver, makes the pathogenesis of type 2 diabetes complex and unclear. Increased glucose levels in liver stimulates both fatty acid and triglyceride synthesis this has significant effect in type 2 diabetes as the thresh-

old increases and causes reduction in insulin sensitivity resulting in increased secretion and synthesis of triglycerides. As it is learnt that Impaired glucose metabolism leads to the changes in lipids. It is now understood that increase in the levels of triglycerides causes elevation in free fatty acid levels thereby causing reduction in insulin sensitivity (insulin resistance) and also leading to dysfunction of β-cells [25,26]. it is hypothesized that increased fatty acid concentrations disrupts the cascade mechanism of insulin receptors with glucose transporters causing impairment of β-cell function [27]. Free fatty acids are the modulators of inflammation. Considering this feature it is hypothesized that hypertriglyceridemia induces subclinical inflammation further causing β-cell dysfunction and insulin resistance. This explains the fact that glucose metabolism is worsened in diabetic patients with hypertriglyceridemia and difficult to control hyperglycemia when compared to the diabetic patients with normal triglyceride levels. In this scenario high density lipoproteins (HDL) is learnt to play a promising role in improving glucose metabolism i.e. higher the levels of HDL-C lesser is the hyperglycemia. In a study, the infusion of HDL in diabetic patients showed improved glucose metabolism. HDL is learnt to stimulate reverse cholesterol transport and also alters the intracellular lipid concentration thereby reduces micro-inflammation [28,29]. The role of apo-lipopreotein A1 (apoA) in lipid as well as in glucose metabolism was also studied in an animal mouse model. It showed that overexpression of apoA1improve glucose metabolism, contributes for higher lean body mass and also causes higher expression of mitochondrial ATP synthase enzyme. Also find the interesting fact that overexpression of apoA1 may also prevent the obesity induced through diet. This clarifies the clinical point that not just increased glucose levels or disturbances in glucose metabolism lead to dyslipidemia as a consequence but also learnt that it could be the cause of glucose dysregulation too. From this statement it can be derived that low levels of HDL-C are at high risk to develop type 2-diabetes when compared to the individuals with good HDL-C levels.

Many studies are taken up to understand the link between glucose and lipid metabolism even at molecular level but still this field of research is unsuccessful. It is a complex pathway hence, its mechanism remains obscure. But one could derive the information that consumption of excess glucose or carbohydrate diet shouldn't be considered as healthy diet and the same is applicable for protein and fat diet too. As excess glucose contributes for lipid synthesis, acetyl CoA being the common precursor for various pathways like fatty acid synthesis, cholesterol synthesis, ketone bodies etc;. It is always recommended to consume a mixed diet. A diet with fibers, carbs, fats and oils, proteins depending upon one's bodies requirements.

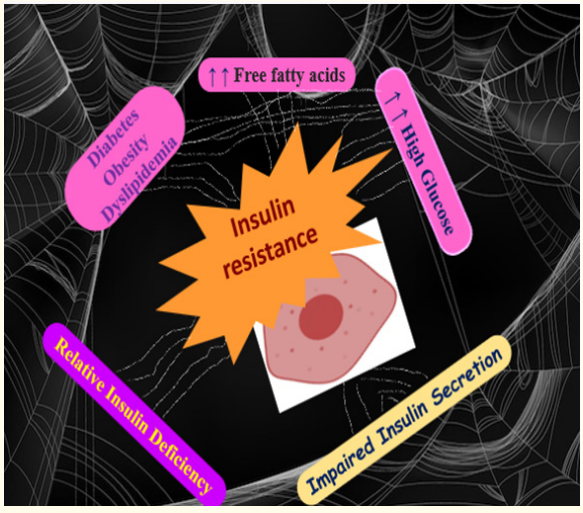

Figure 3: Glucose toxicity.

Discussion

Most of the people generally prefer to have palatable and attractive food hardly considering its nutritious value. On consuming Carbs or sugar rich food regularly will soon become addiction and will develop craving for the same. Glucose being an instant energy molecule, simple, soluble carb thought be included in the regular diet. But, the fact is never denied, that it has, its impact on various metabolisms too. Hyperglycaemia is fatal when not control, the complications related to this has the impact on almost all the organ and every part of the body right from head to toe. Glucose as it simple molecule it is toxic too when consumed in higher concentration. One should understand that direct carbs are not required in the regular diet who consumes food regularly at regular intervals. In this review it is well elaborated on the role of glucose on various metabolism and the interlink between both glucose and lipid metabolism. Since years people are under impression that carbs are easily digested hence can be consumed at higher amounts. This is applicable only for infant, children and individual with digestive problems. It is also suggestive to consume food when required, mostly raw or uncooked or semi-cooked food was consumed in the early ages. Hence, our ancestors had less health complications and rare metabolic syndrome. It is not even suggestive to consume same type of the meal three times a day. Our digestive enzymes, hormones work accordingly depending on the physical activity and climatic conditions. Diet should also be planned in the similar man-

ner for instant, good protein diet in winter and carbs, citrus, juicy fruits in summer, etc; glucose and lipid metabolisms are linked with each other in various tissues and has complex mechanism the exact reason for the complications raised by glucose and its impact on various lipid metabolism is still unclear. Wherein, thousands of researchers worked on this topic of interest. But, haven't provided much fruitful information. By far glucose is learnt to be a source for lipid and triglycerides synthesis.

Hence, one can derive the conclusion that hypertriglyceridemia is not just a complication but also a cause of abnormal glucose metabolism. The common conclusion derived from various research studies related glucose is that high glucose will contribute for fat synthesis and excess fats cause insulin resistance and β- cell dysfunction and has the same effect exclusively with high fat content too. It is recommended to have regular check on sugar levels, as high glucose has toxic effects causing toxicity of retinal capillary endothelial cells, neurons, mesangial cells of renal glomerulus and Schwann cells of the peripheral nerves causing neuropathy, nephropathy and retinopathy [30,31]. This also has an additional complication include development of cardiovascular diseases, inflammation in osteoarthritis and progression and proliferation of cancer cells. Considering all the facts it is understood that glucose is a tiny, mischievous, trouble-creator among the world of molecules. Its taste attracts us as it has irresistible charm but one should be cautious about its toxic effects on our body, as it has the potential to damage every single cell of our body right from head to toe. We have practice of being very conscious while having fat rich food designating it as cholesterol rich food and are also under impression that one should avoid fat rich food when in dieting and are ignoring the fat that consumption of high carbs or cabs exclusively, is equally damaging. Notorious glucose in excess will not only hinder its own metabolism and functions but also disturbs the other metabolisms causing many complications as explained above.

Conclusion

Glucose is indispensable for the body functions and moderation (self-restraint) is the only remedy to avoid its potential toxic effects. Excess sugars stimulate the lipid metabolism, contribute towards the synthesis of fats. Hence, one should not just be conscious while consuming fat rich food but should be conscious when enjoying the sugars in your meal too. Overall, balanced diet with regular physical activity is at most important to lead a healthy lifestyle. So, it is recommended to have an eye on the darker side of the sweet glucose while enjoying your delicious.

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