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A Review on the role of carbohydrates in the management of diabetes and obesity

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Abstract
Background: Carbohydrates are organic molecules composed of carbon, hydrogen and oxygen in the ratio of 1:2:1. They are categorized based on the number of sugar units and how the sugar units are chemically bonded to each other. Categories include sugars, starches, and fibers. Numerous studies point that carbohydrates are the root cause of obesity and diabetes.
Objective: The present review is focused on the nature of carbohydrate and its association in managing the risk of Type 2 diabetes and obesity.
Methodology: This review of literature was carried out from Scopus and PubMed articles published between January 1977 and November 2020. This systematic review has been done by reviewing 75 review papers. We included human studies, adults (18 years or older). Only studies that reported the direct effect of carbohydrates, fibers, starches, sugars and added sugars were included.
Presentation: Carbohydrates plays multiple role in the body right from performing as an energy source, helps in controlling blood glucose and insulin metabolism, maintaining muscles, participate in cholesterol and triglyceride metabolism, and help with fermentation, promoting gut health and preventing constipation. Healthy carbohydrate sources is been discussed.
Conclusion: The general rule of low carbohydrate diet for the management of diabetes and obesity has to be changed. Not all carbohydrates are bad. Based on the source and type of carbohydrates the mechanism of action in the body varies, so the results and the management of diabetes and obesity.

Keywords: carbohydrates, glycemic index, glycemic load, diabetes, obesity, health

Introduction
Carbohydrates are organic molecules composed of carbon, hydrogen and oxygen in the ratio of 1:2:1. [1]. All carbohydrates are made up of sugar molecules which are linked together to form starch and fiber. Carbohydrates are categorized based on the number of sugar units and how the sugar units are chemically bonded to each other. Categories include sugars, starches, and fibers [2].
Carbohydrate is known to be the only macronutrient with no established minimum requirement. For centuries though human beings have survived on diets with varying macronutrient ratios, the recent trend of consuming rapidly digestible, high Glycemic Index carbohydrates in developed nations has led to the epidemics of obesity and other metabolic diseases. Traditional starch based diets along with decrease in physical activity and higher body mass index mostly due to rapid urbanization have also contributed to rising risk of chronic disease in some of the developing countries including India [3].
Studies on dietary patterns of different segments of population have led to the conclusion that high carbohydrate intake is associated with higher risk of metabolic diseases leading to total mortality [4].
Though numerous studies pointed that carbohydrates are the root cause of obesity, abnormal metabolism and leading to metabolic diseases like diabetes, there are studies as well as authors previous research highlighting that right (unrefined) type of carbohydrates plays a positive role in metabolism as well as overall wellbeing of the body. Hence, the present review is focused on the nature of carbohydrate and its association in reducing the risk of Type 2 diabetes and obesity.

Methodology
Data sources and searches
This review of literature was carried out from Scopus and PubMed articles published between 1 January 1977 and November 2020. The following keywords on MEDLINE/PubMed and Google Scholar were used: (‘carbohydrate’ OR ‘low carbohydrate’ OR ‘low carb’ OR ‘high carbohydrate’ OR ‘high carb’) AND (‘composition’ OR ‘diet’ OR ‘dietary’ OR ‘intake’ OR ‘determinant’) AND (‘obesity’ OR ‘obese’) AND (‘Diabetes’ OR ‘Type 2 Diabetes’ ‘prevalence’) [5].

Study screening and selection
This systematic review has been done by reviewing 75 review papers. We included human studies, adults (18 years or older). Only studies that reported the direct effect of carbohydrates, starches, sugars and added sugars were included based on the following inclusion and exclusion criteria.

Inclusion and exclusion criteria
For this review, the inclusion criteria were as follows: (i) Clinical human studies that includes observational study, randomized controlled trial, AND double-blind randomized controlled trial or single-blind, non-randomized controlled

trial design, AND (ii) studies involving human adult subjects, AND (iii) studies examining the effects of carbohydrate sources like rice, legumes, roots and tubers, fruits and vegetables.

The exclusion criteria were as follows: (i) studies that investigated the impacts of an individual bioactive component of carbohydrates, OR (ii) studies on animals. or blog articles were excluded

Data extraction and management

The articles were screened in three phases before they were included for the present review study. In the first phase, the title of the articles that did not match the inclusion criteria was excluded. In the second phase, abstracts of the remaining studies were screened, and later, the studies that did not meet the set inclusion criteria were excluded. In order to standardize the data collection, all data extraction was performed independently with the use of a data extraction form which was MS. Excel.

Review presentation

The paper is presented under different sub headings.

1. Role of carbohydrates in health
2. Glycemic Index and Glycemic Load-Nature of carbohydrate
3. Carbohydrates in Diabetes and obesity
4. Healthy Carbohydrate sources
5. Recommendations for carbohydrates, Fiber and sugars
6. Strength and Weakness of the study
7. Future recommendations

Role of carbohydrates in health

Being a macronutrient, carbohydrates performs multiple roles in our body. The most important role is Carbohydrates serves as the primary energy source for people. When we consume carbohydrates, they get digested and broken down into simpler form, the glucose before entering the bloodstream. Study reported that when a mixed meal consisting of three macronutrients, carbohydrates, proteins and fats is consumed, the body cells prefer carbohydrates as their prime source of energy [6].

Excess carbohydrates are stored as glycogen in the liver and muscles. This will help in maintaining normal blood glucose levels. The glycogen content in skeletal muscles will play a balance between available glucose and insulin sensitivity in skeletal muscles [7].

During starvation, especially reducing carbohydrates in the diet leads to the breakdown of muscles to provide energy for the functioning of the central nervous system. This will lead to the loss of muscles. Hence adequate carbohydrates are required for the maintaining the muscles [8].

The protective role of unrefined carbohydrates is reflected in a 'consistent, inverse association between dietary whole grains and the incidence of cardiovascular disease [9]. Carbohydrates plays multiple role in the body right from performing as an energy source, helps in controlling blood glucose and insulin metabolism, maintaining muscles, participate in cholesterol and triglyceride metabolism, and help with fermentation, promoting gut health and preventing constipation. These studies highlights that the quantity and the quality of carbohydrates in the diet influence blood glucose levels, influencing insulin secretion and gastric emptying [10].

Glycemic index and glycemic load

Glycaemic index (*GI*) denotes the glucose-raising effect of a food in comparison with a standard glucose-containing equivalent amount of carbohydrate whereas glycaemic load (*GL*) is a product of the *GI* and available carbohydrate content per serving of the food [11].

Previous observational studies also reported that the *GI* of the diet may be an important determinant of metabolic risk. Consumption of high *GI* foods results in the rapid rise in the level of blood glucose, a large insulin response, and the release of glucagons is strongly inhibited [12].

Observational data reported that the diets with a high glycemic load and low cereal fiber content increases the risk of type 2 diabetes [13]. Similarly, the glycaemic index of foods can influence body-weight control [14]. Short-term studies suggest that low *GI* carbohydrate foods such as fiber consumption could delay hunger, decrease the subsequent energy intake compared with high *GI* foods [15] such as refined grains, potatoes, and sugar sweetened beverages [16]. Whole grains, legumes, and whole fruits are associated with reduced risk [17].

Carbohydrate quality determined by the glycemic index (GI) and the glycemic load (GL) reported that low GI and GL diets were associated with lower risk for diabetes compared with diets with higher *GI* and *GL*, independent of the amount of cereal fiber in the diet [18].

The restriction of carbohydrates in the diet produces depletion in the glycogen stores leading to the excretion of bound water, and ketogenic effect. But, low-*GI* foods are high in fiber content, which prolongs the distension of the gastrointestinal tract, causing increased and prolonged secretion of the gastrointestinal hormones such as gut peptides cholecystokinin, ghrelin, glucagons, glucagons-like-peptid-1, and glucose-dependent insulinotropic polypeptide, all of which have been reported to be potential satiety factors [19].

Carbohydrates in diabetes and obesity

Carbohydrates are mostly reduced in the diets of diabetes as well as obesity stating that it may cause increased blood sugars or weight gains.

The overall prevalence of diabetes, based on a study of 15 whole States of India, was 7.3 per cent [20]. The Chennai Urban Rural Epidemiological Study reported that in Asian-Indians from the urban regions of south India, the dietary carbohydrate and glycaemic load (*GL*) were linked to increased risk of type 2 diabetes. The predominant intake of carbohydrates from polished grains in Indian diets also means that they are low in other healthy carbohydrate foods such as whole grains, fruits and vegetables [21].

A prospective cohort study shows that a high *GI* and a high *GL* diet increase the risk for diabetes [22]. Observational studies indicate that the *GI* of the diet may be an important determinant of metabolic risk. The major sources of carbohydrates which are mostly refined cereals tend to have high *GI* values, which has been linked to the widespread occurrence of diabetes and cardiovascular diseases [23]. A diet high in rapidly absorbed carbohydrates and low in cereal fiber is associated with an increased risk of diabetes [24]. International committees found moderate to strong evidence associating an increased risk of diabetes with a higher consumption of free/added sugars in the form of sugars-sweetened beverages [25].

How carbohydrates help in diabetes

Evidence based research suggests that it is not the relative carbohydrate proportion of a diet influences the risk for diabetes; but, a diet rich in fiber, preferably the cereal fiber, may reduce the risk of diabetes [26]. In a meta-analysis of *RCTs* with interventions of more than four weeks among people with diabetes, participants on a low-*GI* diet had a significant reduction in HbA1C than those on a high *GI* diet [27].

Dietary fiber, the edible part of the plant or carbohydrates which are resistant to digest and absorb in the human small intestine with complete or partial fermentation in the large intestine [28] is considered to be a functional food because of its diverse function in the body. Soluble fiber which is known in delaying the glucose absorption from the small intestine thus, may help prevent the spike in blood glucose levels after a meal or a snack. The long-term effect may be insignificant, due to the many other factors that affect blood glucose [29]. Fiber intake is shown to be associated with lower postprandial glucose levels and increased insulin sensitivity in diabetic subjects. These effects were attributed to the viscous and/or gelling properties of soluble fiber [30].

How carbohydrates help in obesity

According to ICMR-INDIAB study 2015, prevalence rate of obesity and central obesity varies from 11.8 per cent to 31.3 per cent and 16.9 per cent to 36.3 per cent respectively [31]. Cereal based carbohydrates provide the bulk of the energy in the Asian Indian diets [32]. It is known that high-carbohydrate diets mainly refined carbohydrates raises plasma glucose, insulin, TAG and NEFA and thus contribute to insulin resistance [33] which also leads to weight gains.

A meta-analysis of *RCTs* indicates that reduced or increased intake of free sugars such as fructose or corn sugar promotes, respectively, loss or gain in body weight respectively [34]. Also, long-term dietary as well as lifestyle interventions reported that consumption of a relatively high-carbohydrate diet (≈55 per cent of energy) that includes high amounts of fiber-rich foods can be compatible with clinically relevant weight loss [35]. Earlier, whole cereal-based carbohydrates provide the bulk of the energy in Asian Indian diets [32]. However, today, they are replaced with refined carbohydrates, predominantly from rice, due to modern milling technology [36]. This refined high-carbohydrate diet is known to raise plasma glucose, insulin, TAG and NEFA and thus contributing to insulin resistance as well as obesity [37].

Fiber, the indigestible carbohydrates plays an important role in reducing obesity. Multiple studies from across the globe reported that fiber intake is important to prevent obesity and other lifestyle disorders [38]. Many clinical studies have shown a moderate weight loss of five to ten per cent in obese patients reduces the risk factors of metabolic disorders by following a dietary modifications in the diet by consuming fiber rich foods [39].

Indian studies reported that increased consumption of fiber in diet through intake of fruits, vegetables, whole grain cereals as well as pulses should be encouraged to lose weight [29].

Also, studies reported strong association between gut health and obesity. In human gut, there are two groups of beneficial bacteria, the Bacteroidetes and the Firmicutes. The relative proportion of the Bacteroidetes is seen to be decreased in obese people when compared with that of the lean people. Moreover, this proportion increased with weight loss on two types of low-calorie diet [40] or adequate fiber rich diet.

The indigestible carbohydrates such as fiber and resistant starch are good sources of *MACs,* that are utilized by microbes in the large intestine to provide the host with energy and a carbon source. Thus, inclusion of higher quality whole grains or bran can increase butyrate production, thus helping increase the biodiversity of the gut microbiota [41].

Multiple factors impact the diversity and composition of the gut microbiota leading to dysbiosis, which is associated with weight gain and obesity. The influence of the intestinal microbiome on metabolism, hormone balance, neurotransmitter function, and the brain can play a major role in weight management and treatment of obesity. Previous researches reported that the gut microbiota increases energy production from food, provides low-grade inflammation, and impacts fatty acid tissue composition. These mechanisms may link the gut microbiota with obesity [42].

Healthy carbohydrate sources

Carbohydrates are comprised of a wide range of saccharides and current nutritional recommendations are based on their classical chemical classification. If consumed the whole /healthy carbohydrate sources, there will be overall beneficial effect on the body. The healthy carbohydrate sources are discussed below.

Legumes

Legumes are known have a low-energy density and are nutrient dense [43] and majority of legumes contain phytochemicals, the bioactive compounds, including enzyme inhibitors, phytohaemagglutinins (lectins), phytoestrogens, oligosaccharides, saponins and phenolic compounds. Dietary intake of phytochemicals through regular legume consumption in the daily diet may provide health benefits, thus protecting against several diseases [44].

A three months intervention study among T_2D participants who were on either a low-*GI* and legume based diet or a diet with higher insoluble fiber from wheat based products showed that the HbA1c values were reduced by 0.5 per cent in the low-GI legume diet as compared to the high wheat fiber diet (-0.3%). Thus, inclusion of whole grain legumes in the diets not only improves the protein and dietary fiber intake but also improves the glycaemic properties of the diet and thus help in Chronic Heart Diseases risk reduction in patients with T_2D [45]. Consumption of legumes provides quality protein along with other micronutrients without adding extra energy or fat. Also, the fiber content in the whole legumes enhances gut health and is recommended in the prevention and management of obesity and chronic diseases including diabetes and cardiovascular disease [46]

Whole grains

Whole grain consists of the starchy endosperm, germ and bran. The outermost layer of a whole grain is the bran, which contains mainly non-digestible carbohydrates and the inner layers of the grain-the endosperm and the germ consist of soluble fibers, resistant starch, vitamins, minerals, and various other phytonutrients (polyphenols and others) [47].

Whole grains are concentrated sources of indigestible

carbohydrates such as dietary fiber, resistant starch and oligosaccharides, which are fermented in the gut, producing short-chain fatty acids (SCFA). SCFA lowers colonic pH, as well as serves as an energy source for the colonocytes and may also alter blood lipids besides maintaining gut health. These grains are rich in various antioxidants, trace minerals as well as phenolic compounds, which have been linked to disease prevention. Moreover, it contains many other compounds such as lignan, plant stanols and sterols, numerous micronutrients like vitamins (*B-complex vitamins)* and minerals (*Magnesium*) that manage diabetes and obesity [48].

Vegetables

Vegetables are rich sources of fiber, flavonoids, antioxidant compounds (carotenoids, vitamin C and E), folate, and potassium, which have a protective effect on T_2D. Dietary fiber is associated with insulin sensitivity, and improved the ability to delay the absorption of carbohydrates and secrete insulin adequately to overcome insulin resistance, resulting in lower postprandial blood glucose and insulin levels [49].

High intake of dietary fiber in the daily diet promotes the feeling of fullness and reduces the intake of energy dense foods, thus leading to a reduced risk of overweight/obesity, which is an established risk factor for type 2 diabetes [50].

Fruits

Fruits are rich in fiber, antioxidants, and phytochemicals that have beneficial health effects for diabetes as well as obesity [51]. A trial using intact apples with their natural fiber were significantly more satiating than fiber-free apple juice, although both test foods provided 60 grams of carbohydrate. Moreover, fiber free apple juice raised serum insulin to higher levels [52]. Fruits contain various bioactive components such as polyphenols, antioxidants, besides fiber rich. This makes whole fruits anti diabetic and anti-obese [53]. Portion control has to be kept considered.

Roots and tubers

In the diets of diabetes or obese, mostly roots and tubers will be avoided. But, most of the roots and tubers consists of a numerous of bioactive constituents, such as phenolic compounds, saponins, bioactive proteins, glycoalkaloids, phytic acids, and hydroxycoumarins [54]. Consumption of roots and tubers under the recommended levels will be beneficial for overall health of diabetes and obese individuals.

Strength and weakness of the study

Carbohydrates contribute to 55 to 65 per cent of the energy requirement of a daily diet. In this article authors are highlighting that inclusion of whole grains, roots, legumes, vegetables and fruits are beneficial for obesity and diabetes and limiting the intake of refined foods. Also glycemic index and glycemic load in both diabetes and obesity is discussed. Role of carbohydrates was limited only to diabetes and obesity. Other metabolic diseases were not studied. Also carbohydrate requirements in different age groups and physiological status not studied.

Future recommendations

Inspite of recent research findings on the role of carbohydrates especially in diabetes and obesity, there are many areas uncovered. Earlier studies were mostly short duration clinical studies where there was lack of blinding, no control for treatment intensity between the dietary interventions groups, and also had limited compliance. There should be long duration clinical trials covering control for treatment between intervention groups.

Conclusion

Carbohydrates form a diverse group of foods having numerous functions in the body. All carbohydrate foods do not have same metabolic effect in the body. Consuming carbohydrates always will not lead to increased blood sugar levels or weight gains. Consuming a diet comprising of whole grains, fruits, vegetables, legumes, nuts, moderate in alcohol consumption, and avoiding refined grains, red/processed meats, and sugar-sweetened beverages proves to reduce diabetes risk and improve glycemic control and blood lipids in patients with diabetes. Finally a balanced diet consisting healthy carbohydrate sources with adequate proteins and fats based on individual and cultural food preferences as well as based on physical activity and physiological status will results in weight control as well as diabetes management.

Conflict of Interests

Nil

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