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Review Article

Nutrition and Its Link with Diabetes in Asian Indians: Challenges and Solutions

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Diabetes rates in Indians have reached epidemic proportions. The main drivers of this epidemic are unhealthy eating habits and physical inactivity. Epidemiological studies and various clinical trials have shown the significance of diet in prevention, as well as management of type 2 diabetes (T2D). The diet of Indians consists predominantly of refined cereal grains (like white rice or refined wheat), which contribute to half of the daily calories. Hence, the dietary glycemic load of Indian diets is very high and this is associated with a higher risk of diabetes. Indian diets are also low in vegetables, fruits and mono unsaturated fatty acids adding to the risk of T2D. The quality and quantity of carbohydrates and fats need to be addressed if we are to prevent diabetes. Our group recently demonstrated the benefits of brown rice (whole grain) and cashew nut consumption with respect to reduction in cardio-metabolic risk factors. Changing the food environment by creating healthier food choices and making them available, accessible and affordable through various policy driven nutrition programs is an important step. Collaboration with agricultural and food scientists could help to develop healthier cereals and other food products. Health care professionals play a vital role in bringing about behavioral changes in the population helping them to choose right foods in the right quantity. This, combined with increasing physical activity, could help to stall, or at least slow down, the epidemic of T2D in Indians.

Keywords: Diabetes; Metabolic Syndrome; Nutrition Transition; Glycemic Index; Prevention

Introduction

Nutrition Transition and Type 2 Diabetes Risk

There has been a rapid increase in the prevalence of type 2 diabetes (T2D) in India. Rapid nutrition transition, reflected in unhealthy eating habits and physical inactivity are the main drivers of diabetes epidemic (Anjana *et al.,* 2015; Anjana *et al.,* 2017). Over 0.9 million deaths in India in 2015, were attributable to diabetes.

The term 'Nutrition transition' refers to the changes in the composition and consumption pattern of the diet, consequent to improvement in socio-economic status, which is usually accompanied by changes in physical activity levels. The nutrition transition leads to diets high in refined carbohydrates, sugar, saturated fat, processed foods and low in coarse grains, legumes, vegetables/fruits and dietary fibre, all of which lead to obesity and T2D (Popkin, 2015). Cultural traditions, geographical, environmental, social and economic factors and aggressive marketing by industry alter the dietary patterns of a population over a period of time.

Asian Indians have higher pre-dilection to T2D and coronary heart diseases and this is referred to as 'Asian Indian Phenotype'. This includes features such as; increased waist circumference, higher central and/or visceral obesity, dyslipidemia and insulin resistance.

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Moreover, Indians in both urban and rural areas now have markedly low physical activity levels (Anjana *et al.,* 2014).

This article focuses on the link between nutrition and diabetes, and discusses the various diabetes risk reduction strategies that one can take up based on healthier nutrition coupled with increased physical activity levels.

Origins of the Nutrition Transition in India

Till the 1960's, India faced acute food shortages and was dependent on western aid for its food sufficiency. The green revolution in India in the 1960's and 70's made India self-sufficient in food. This lifted India out of hunger and famine to a situation of food surplus although inequitable distribution of food is still a problem. Technological innovations enhanced consumption of relatively cheaper unhealthy processed foods, rich in refined grains, oils, salt and sugar in India which is strongly associated with the T2D epidemic (Krishnaswamy *et al*., 2016). Simultaneously, consumption of healthy foods - whole grains, nuts, fruits and vegetables has reduced (Ramachandran P, 2011).

Due to modernization and technological advancements, whole grain cereals have been replaced with polished white rice, depleted in fibre and other nutrients. Consumption of such refined grains leads to higher dietary glycemic load (GL), associated with insulin resistance and T2D (Mohan *et al.,* 2009).

Diet, Weight Gain and Adiposity

The risk of T2D rises as body fat increases particularly the abdominal fat (Anjana *et al*., 2004). Higher intake of refined grains was positively associated with increased body weight and waist circumference among urban adults (Radhika *et al*., 2009a). Conversely, an inverse association of fruit and vegetable intake was observed with BMI and waist circumference (Radhika *et al*., 2008). Even among rural adults, a greater prevalence of generalized and centralized obesity was seen among those who consumed higher amount of refined grains (Sowmya *et al*., 2016).

The various macro-nutrients and their association with T2D are as follows:

Macronutrients

Carbohydrates

Glycemic index (GI) : Carbohydrate quality is measured by glycemic index (GI). Foods are categorized as high GI (>70), Medium GI (56-69) and low GI (<55). High GI foods elicit a higher glycemic and insulinemic response and mediate T2D risk through beta cell exhaustion and insulin resistance. Carbohydrate restriction, as low as 33 percent of calories, was considered as the key dietary advice in India in the 1950's. However, this was not sustainable as Indian diets are mostly cereal based and hence high in carbohydrate content (Viswanathan and Mohan, 1991). Burden *et al.* (Burden *et al*., 1994) reported an increase in glycemia and insulinemia, 2 h after an Asian Meal (carbohydrates ~45% energy compared to a European meal ~25 %). High GI foods such as refined grains provide 50% of the total energy among urban and 70% in rural adults (Narasimhan *et al*., 2016) and have been found to be associated with metabolic syndrome (MS) (Radhika *et al*., 2009a) and T2D risk (Mohan *et al*., 2009). The factors affecting the GI of foods are shown in Fig. 1.

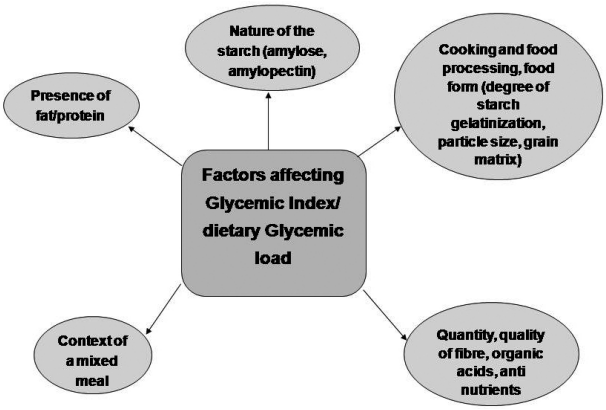

Fig. 1: Factors affecting Glycemic Index of food

Glycemic Load

In addition to the GI, the quantity of carbohydrates is also important. The glycemic load (GL) of diet is based on the carbohydrate content measured in grams (g), multiplied by the food's GI, and divided by 100. Similar to GI, GL are categorized as high GL (>20), medium GL (11-19) and low GL (<10).

Apart from increasing the predisposition to T2D, the dietary GL also decreases the good (HDL)

cholesterol (Radhika *et al*., 2009b) which may exacerbate the Asian Indian dyslipidemic phenotype characterized by high triglycerides and low HDL cholesterol. Misra *et al*. (Misra *et al*., 2001) reported that a higher percentage of energy from carbohydrate intake was positively correlated with serum triglyceride levels even among Asian Indians of low socio-economic status. Large carbohydrate meal is very common in Asian Indians, especially at dinner time, which may lead to hyperinsulinaemia and postprandial hyperglycaemia. A proper distribution of carbohydrates in three to five meals a day would be advisable to prevent the deleterious effects of carbohydrate overloading (Misra *et al*., 2008). Thus, it is clear from the above that the dietary GI and GL as well as the total carbohydrates need careful consideration in Indian diets.

Conversely, a decreased risk for T2D was observed with a higher dietary fibre intake (Mohan *et al*., 2009). A higher prevalence of hypercholesterolemia (higher LDL cholesterol) was observed among individuals with T2D who consumed less than 29g of dietary fibre/day (Narayan *et al*., 2014).

There are several studies to support a reduced risk of CVD, T2D and obesity with a higher whole grain intake. We (Mohan *et al*., 2014) demonstrated 20% and 57% reductions with brown rice (BR)-based diets in the 24 h glycemic response and fasting insulin levels compared to white rice (WR) diets in overweight adults. However, poor sensory attributes of BR (dull appearance, chewy texture and prolonged cooking time) are a challenge for its promotion in the community. Hence, there exists a demand for WR with lower glycemic properties. Recently, we have developed a high fibre white rice (HFWR) by using classical plant breeding techniques and this rice variety has a five-fold higher dietary fibre content compared to WR and a much lower GI (61) compared to the GI of commercial WR (79) (Mohan *et al*., 2016). Nutrition sensitive agriculture is essential to make healthy choices available.

Whole grain based preparations elicit lower glycemic response as compared to refined flour based preparations. Grains in their most intact form, contain starch granules encapsulated in the protein matrix inside cell walls, which are less amenable to amylolytic enzymes unlike the starch granules in refined flours, where the grain matrix is completely lost.

Millets, which are slowly gaining importance, are undoubtedly, healthier than WR or refined wheat owing to the higher protein, dietary fibre, vitamins and mineral composition. However, small millets especially foxtail, little, kodo, barnyard and proso millets are mostly polished like WR and are fibre depleted, unlike finger millet (FM) and pearl millet. There are very few studies on GI of millets. Shobana *et al*. (2018) showed that FM despite high dietary fibre content exhibited high GI when consumed in the form of '*upma'* prepared from decorticated (refined) FM. Vermicelli '*upma'* and ready- to-eat extruded snack enriched with soluble fiber and defatted soy flour was of medium GI. However, wholegrain flakes upma had high GI due to gelatinization during processing. Refining grains and processing foods reduce functionality. However, addition of soluble fiber reduces the GI.

Intake of sugar sweetened beverage (SSBs) and total sugar intake is increasing among Indians. Frequent consumption of high fructose-sweetened beverages has been reported to have adverse effects on lipid metabolism, blood pressure and insulin sensitivity, especially in overweight and obese people. Naturally occurring fructose from whole fruits is unlikely to be deleterious. However, regular consumption of sweetened fruit juices is not recommended. Non-nutritive sweeteners could help in reduction of overall calorie and carbohydrate intake, and thus aid in weight reduction and improve glycaemic control, but the long-term safety needs to be investigated (Shankar *et al*., 2013).

Fats

Low fat diets were traditionally recommended to reduce the risk of cardio-metabolic risk factors without much attention to the quality of fat. However, there is increasing emphasis on the dietary fat quality in the current global and national guidelines (FAO-WHO, 2010; RDA, 2012). In India, fat consumption has been increasing in both rural and urban areas (Meena *et al*., 2016). However, Indian diets are still relatively low in fat content compared to other parts of the globe, with the main source being plant rather than animal fat. The former is lower not only in saturated fatty acids (SFA), but also in n3 polyunsaturated fatty acids (PUFA) and monounsaturated fatty acid (MUFA). The composition of fats and oils is specific to regions and is income dependent as well.

Saturated Fat

Earlier dietary guidelines recommend limiting SFA intake to less than 10% of energy by replacing them with unsaturated fatty acid for people with diabetes and in dyslipidemia to restrict the SFA intake < 7% of energy (Misra *et al.,* 2011a). However, there is mixed evidence about SFA and disease risk and a recent study (Dehghan *et al.,* 2017) reported that replacement of SFA with carbohydrates was associated with adverse effects on lipids, whereas replacement of SFA with unsaturated fats improved LDL cholesterol and blood pressure, but worsened HDL cholesterol and triglycerides. Some studies have reported an association between high fat in the form of saturated fat and cardio-metabolic risk factors such as obesity, hypertension and insulin resistance (Narasimhan *et al.,* 2016).

Polyunsaturated Fatty Acids (PUFA) and Monounsaturated Fatty Acids (MUFA)

Sunflower oil (high n6-PUFA) has also been shown to have a positive association with MS in both rural and urban adults (Narsimhan *et al*., 2016; Lakshmipriya *et al*., 2013). Improving the MUFA content could improve blood glucose, serum insulin, lipids and inflammatory markers. A lower intake of refined cereals (<300g/day) intake, with increased intake of fruit and vegetables (~400 g), dairy (~500g -3% fat) and 20 g of MUFA derived from edible oil and nuts, could prevent 30% of new onset diabetes (Anjana *et al.,* 2015).

The linoleic acid (LA, omega-6 PUFA) is the most abundant fatty acid available in many plant products. An ideal Indian diet will contribute desirable amount of LA from plants despite the type of cooking oil used. The consumption of marine fish, a major source of long chain omega 3 PUFA, is very low (Ghafoorunissa, 1996; Dwarkanath *et al*., 2009). Alpha linolenic acid (ALNA) is the major omega 3 fatty acid in Indian diets. Inclusion of leafy vegetables, legumes and fish could ensure to maintain a healthy ratio of 5-10 between linoleic and ALNA (NNMB, 2012). Use of sunflower oil (high in omega-6 PUFA) compared to traditional oils like groundnut oil has increased n6:n3 ratio both in the urban and rural population which has been linked to risk of components of MS (Narsimhan *et al.,* 2016; Lakshmipriya *et al*., 2013; Misra *et al*., 2008). Conversely increased dietary MUFA intake was associated with decreased incidence of T2D in the Chennai Urban Rural Epidemiology Study (CURES) (Anjana *et al.,* 2015). MUFA rich nuts like cashewnut (30g/day for 3 months) was associated with an increase in HDL cholesterol and a decrease in blood pressure in a recent randomized trial in T2D participants (Mohan *et al.,* 2018) and almonds (contributing 20% of the total energy intake) showed improvement in the lipid profile and reduction in glycosylated haemoglobin thereby showing its beneficial effects on glycemic and CVDs risk factors in Asian Indian patients with T2D (Gulati *et al*., 2017). Canola oil is reported to reduce metabolic risk (Misra *et al*., 2010). Kuriyan *et al.* (2005) showed that the cholesterol-lowering properties of rice bran and mustard oils reduces the risk of T2D (Raheja *et al*., 1993). Quality of fat is as important as quantity of fat for risk profile of chronic diseases.

Protein, Fruit and Vegetables

Initially, dietary recommendations for individuals with diabetes were focused on carbohydrates and fats and proteins were ignored. Ingestion of protein results in small reductions in the postprandial glucose concentrations. Protein intake in the urban and rural population decreased by10% over last 2 to 3 decades (Misra *et al.,* 2011b). Hence efforts must be taken to improve the quantity and quality of protein in Indian diets by inclusion of more legumes, low fat dairy products and fish or chicken for non-vegetarians. Agrawal and Ebhrahim (2013) showed an inverse association with diabetes with higher intake of legumes. There is also a negative association between dairy consumption and T2D (Mohan *et al*., 2009) and more recently higher consumption of dairy has been reported in India (Popkin *et al*., 2012).

Animal foods (rich in dietary protein) intake is increasing in India (Popkin, 2009) and it is important to note that animal food pattern was positively associated with anthropometric risk factors in the Indian Migration Study (Satija *et al*., 2015). Consumption of plant based (rich in dietary protein) healthy foods is low with less than three servings a day in the urban areas of India (Radhika *et al.,* 2011). Higher intake of fruits and vegetables showed a protective effect against risk of T2D and CVD (NNMB 2016; Radhika *et al.,* 2008).

Table 1: Randomized clinical trials of dietary intervention in diabetes

Study	Strategy/intervention	Positive results
Ramachandran *et al*. (2006)	Adults with impaired glucose tolerance (IGT) were given advice on lifestyle modification (LSM) and treated with metformin.	LSM significantly ↓ the incidence of T2DM in Asian Indians with IGT
Shrivastava *et al*. (2017)	Medical education for children/Adolescents for realistic prevention of obesity and diabetes and for healthy ageing (MARG) focused on life style education for school children in north India	↓ TV viewing, ↑ fruit intake, ↓ waist-hip ratio, ↑ insulin sensitivity.
Weber *et al*. (2016)	Diabetes Community Lifestyle Improvement Program (D-CLIP), a randomized clinical trial of overweight/obese Asian Indian adults with IGT and impaired fasting glucose were started on a lifestyle curriculum of diet (low-fat diet rich in complex carbohydrates. fresh fruits, vegetables), exercise and metformin was used in a step-up manner if the target A1c was not achieved.	↓ Total energy intake ↑ intakes of fruits and vegetables ↓ incidence of diabetes

Micronutrients

Vitamins and Minerals

There is limited data from India on the association of vitamins and minerals with diabetes. Low maternal vitamin B12 and high levels of folate may increase risk of T2D (Yajnik *et al*., 2008). Low vitamin D levels have also been associated with increased risk of insulin resistance and T2D but the evidence is still weak (Al-Shoumer and Al-Essa, 2015). Low levels of magnesium are associated with insulin resistance. Ingestion of zinc orally improves the glycemic control. Chromium helps in regulation of blood sugar levels at least in experimental studies (Rajendran *et al*., 2015).

Dietary Approaches and Strategies for T2D Risk Reduction

Despite the soaring epidemic, awareness about diabetes remains sub-optimal. The National NCD monitoring framework has set out to halt the rise in obesity and diabetes prevalence by 2025 (NCD Risk Factor Collaboration, 2016). Almost 80% of incident diabetes in a longitudinal follow up study was attributable to four factors: unhealthy diet score, physical inactivity, obesity and dyslipidemia (Anjana *et al.,* 2015).

Gaps in Knowledge and Future Directions for Nutrition Research on Diabetes:

- Culture and region specific well designed nutrition intervention trials and epidemiological studies are needed to derive evidence based dietary guidelines specific to Indians.
- Understanding of the individual/ societal drivers and the barriers for healthy eating should be captured before planning and promoting a healthy diet.
- There exists an urgent need for database on the nutrition composition for commonly consumed Indian cooked and processed foods by validated methods.
- There is a felt need for development of Indian meal exchange lists including quality of macronutrients in the diet.
- Eco and agriculture friendly crops like millets deserve attention not only for food security but also as healthier alternatives.
- GI studies on plain cooked small millets both in polished as well as unpolished forms using validated protocols are lacking and need to be undertaken.
- Agricultural scientists should come forward for adopting modern biotechnological approaches for developing new cereal/grain varieties with higher fibre content and lower glycemic properties and oil seeds containing higher omega 3 fatty acids.

Table 2: Proposed dietary strategies for diabetes risk reduction

Strategies/Interventions	Stake holders	Expected Impact
Create awareness ● for reading food nutrition labels, ● minimally polished cereals and millets. Healthy cookery tips to include functional ingredients like fenugreek and other soluble fibre in various meal preparations	Media: Print & TV, digital communication	Empower consumer to make choices of food ↑ awareness about diabetes, healthy life style and significance of high carbohydrates, Gl, GL of Indian diets.
Nutrition education programs on ● improving diet quality which covers quality & quantity of carbohydrates, fats, ● adverse effects of fast/junk foods, sugar sweetened beverages, ● overall healthy Indian meal plate. Encourage physical activity in schools, colleges and corporate sector.	School teachers, diabetes educators, nutritionists, dieticians, family care givers and corporates	↑ awareness right from school age to adulthood on the importance of diet and physical activity.
Government policies, legislations to control sale of unhealthy foods in schools and colleges (Wasir and Misra, 2004).	Ministry of Women and Child Development, Ministry of Health & Family Welfare, Food Safety and Standards Authority of India, Ministry of Human Resource Development	Improve dietary habits of children and adolescent and thus aid in prevention of obesity and diabetes.
Impose taxation (like the Kerala initiative of 14.5% tax on "junk food" sold by organized fast food chain outlets Basu *et al*., 2017) and monitor the benefit	State governments and general public	↓ Junk food and SSB consumption
Develop and introduce low GI grains and products in the market	Agricultural scientists, food technologists, nutritionists, food industry, Ministry of Food Processing	Improve healthy food environment ↓ dietary GL of Indian diets
↑ Availability of fruits and vegetables through reducing wastage (cold chain Miller *et al*., 2016).	Ministry of Agriculture and Farmers Welfare, National Horticulture Mission	↑ intake of fruits and vegetables at an affordable cost
Develop and promote with dietary tools like visual aids to educate high risk population and the care giver of the families about portion control	Food and Nutrition Boards, Agricultural Universities, Home Science Colleges, dieticians, and nutritionists	Enable family members to have portion control of food to aid in weight loss.
Outreach nutrition education programs in rural India	Health care professionals and social workers, Mahila sanghs, ASHA workers, Anganwadi Worker and Helper, Auxiliary Nursing Mid-wife	Improve variety and quality of the diet and promote women entrepreneur to process and develop healthier home made products.
Introduce a subject on applied nutrition and health in the curriculum of not only in schools and colleges but also in medical courses	Ministry of Human Resource Development, national universities including medical universities	Develop basic nutrition skills for all ages and for all professions. Empowerment of medical practitioners to improve the nutritional status of the population.

Conclusions

Unhealthy dietary patterns in combination with sedentary life style are the major drivers for the epidemic of T2D in India. Refined cereals contribute to almost half the daily calories consequently increasing the dietary GL and also enhancing the risk of T2D. The intake of whole grains, vegetables and fruits, nuts is low in Indian diets. The quality and

quantity of carbohydrates and fat need greater focus. Risk reduction strategies could include creating a healthy food environment through various national policy driven nutrition programs involving stakeholders such as agricultural experts and food scientists to develop healthier food products. Multiple stakeholders should come together to encourage behavioral changes by creating awareness and empowering population as a whole or at least those at high risk of diabetes to choose healthy dietary options and increase physical activity as these would help in prevention and management of T2D in Indians.

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