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Review Article

Indian diet: Implications in recent explosion in insulin resistance and metabolic syndromes in India

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Abstract

It has long been suggested that diet is crucial in the development of insulin resistance although conclusive human data is lacking. Indian population is in general considered to be prone to develop insulin resistance and metabolic syndrome. The recent trend in dietary consumption pattern in most of the Indian populations, have several dietary imbalances including; low intake of MUFA, n-3 PUFA and fibre, and high intake of fats, saturated fats, carbohydrates and trans fatty acids (mostly related to the widespread use of Vanaspati, a hydrogenated oil). Some data indicate that these nutritional imbalances are associated with insulin resistance, dyslipidaemia and subclinical inflammation in Indian population. Specifically, in children and young individuals, a high intake of n-6 PUFA is correlated with fasting hyperinsulinaemia, and in adults, high-carbohydrate meal consumption was reported to cause hyperinsulinaemia, postprandial hyperglycaemia and hypertriacylglycerolaemia. Inadequate maternal nutrition during pregnancy that lead to low birth weight and childhood 'catch-up' obesity are also very common in India. Even in rural populations, who usually consume traditional frugal diets, there is increasing prevalence of cardiovascular risk factors and the metabolic syndromes due to rapid pace of change in diets and lifestyle. Dietary supplementation with n-3 PUFA has been shown to improve lipid profile and may have beneficial effect on insulin resistance. Also, low glycaemic index foods and whole grain intake decrease insulin resistance. Among micronutrients, high magnesium and calcium intake have been reported to decrease insulin resistance. This provides a hope that, the grim situation of diet-induced metabolic syndromes can be controlled. Therefore, a nationwide community intervention programmes aimed at creating awareness about the consequences of unhealthy food choices and replacing them by healthy food choices are urgently needed in urban and rural populations in India.

Keywords: Dietary carbohydrates, Indian diet, Insulin resistance, Metabolic syndrome, Trans fatty acids,

Introduction

Diabetes is the single most important metabolic disease which can affect nearly every organ system in the body. It has been projected that 300 million individuals would be diabetic by the year 2025. In India it is estimated that presently 19.4 million individuals are affected by this deadly disease, which is likely to go up to 57.2 million by the year 2025. There could be many possible reasons for this escalation including; changes in lifestyle, increase in aged population (people living longer than before) and low birth weight leading to adulthood diabetes.

Insulin resistance is associated with the metabolic syndrome such as, type 2 diabetes mellitus (T2DM) and cardiovascular diseases (CVD). Impaired insulin sensitivity has been shown in subjects known to be at risk for diabetes, such as normoglycaemic first-degree relatives of patients with T2DM and women with a history of gestational diabetes.

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It is now well established that generalised obesity and abdominal obesity (excess subcutaneous and intra-abdominal fat) are associated with insulin resistance (Misra *et al.*, 2004; Misra and Vikram, 2003; Misra *et al.*, 2007). In most individuals who develop T2DM, insulin resistance is generally present for many years before the occurrence of hyperglycemia.

After few decades of research it has become apparent that diet and physical activity significantly influence insulin resistance, dyslipidaemia and T2DM. The rapidly increasing prevalence of these disorders in various Indian populations has been largely linked to rapid changes in lifestyle and dietary patterns (Misra *et al.*, 2007; Misra *et al.*, 2007 (II); Wasir and Misra; 2004). Unfortunately, the data regarding the relationship of dietary nutrients with insulin resistance are scarce in Indians. Although some studies have reported an influence of dietary nutrients on insulin resistance and cardiovascular risk factors in Indians. The present study aims to review the influence of dietary nutrients on insulin resistance and related metabolic syndromes in Indian populations.

Dietary fats

Several studies have implicated that high dietary fat intake is associated with the development of obesity and hyperglycemia (Himsworth, 1935; Bray *et al.,* 2002; Cornish *et al.,* 2006). A high dietary intake of fat has been reported in Asian Indians (Misra *et al.,* 2001; Yagalla *et al.,* 1996). Fat consumption ranged from 13 to 59 g/d in different regions and states in India. Further, individuals in rural areas in India consume lower (17 %) energy intake from dietary fat as compared with urban residents (22%) (ACCN/ UN, 2002). It has been shown that high intake of dietary fats significantly correlated (correlation coefficient 0·67) with CVD in different regions of India (Misra and Ganda, 2007).

Dietary saturated fatty acids (SFA)

Various investigators have shown that the intake of SFA was a significant independent predictor of fasting and postprandial insulin concentrations (Parker *et al.,* 1993; Maron *et al.,* 1991; Marshall *et al.,* 1997) and that hyperinsulinaemia is decreased by lowering SFA intake (Parker, 1993). Thus, the overall intake of dietary SFA is positively related to insulin resistance, and there is evidence that replacing SFA with MUFA or PUFA (mono unsaturated fatty acid or ploy unsaturated fatty acid) in dietary fat may prevent metabolic deterioration. The mean SFA intake was 6·5% in adult city dwellers belonging to the low socio-economic stratum living in India (Misra *et al.,* 2001). Further, a high mean intake of SFA (9·4% of total energy intake) has been reported in urban Asian Indian adolescents and young adults (Isharwal, 2008). In general, there is a rural-to-urban variation in consumption patterns of SFA, with rural Indians having a low, and urban individuals having a high consumption of SFA.

It has been shown that high intake of SFA is an independent correlate of high C-reactive protein (CRP) levels, a marker for subclinical inflammation, in urban-based adolescents and young adult Asian Indians (Arya *et al.,*2006). Based on these observations, to place them in a low-risk category for future CVD (mean CRP levels,1 mg/l), SFA intake should be decreased to, 7% of energy intake in adolescent Asian Indians.

Polyunsaturated fatty acids

Experimental studies have indicated the beneficial effect of long-chain n-3 PUFA (fish oils) over n-6 PUFA (safflower-seed oil) in preventing insulin resistance, but large scale data from humans is lacking. Some human studies indicate a protective effect of fish intake on the development of insulin resistance (Feskens *et al.,* 1991; Feskens *et al.,* 1995; Popp-Snijders *et al.,* 1987) but results from dietary intervention studies have not been consistent (Giacco *et al.,* 2007). Supplementation with long-chain n-3 PUFA appears to improve insulin sensitivity in subjects with impaired glucose tolerance (Popp-Snijders *et al.,* 1987; Fasching *et al.,* 1991) and in patients with T2DM (Popp-Snijders *et al.,* 1987). Even though it has not been well investigated in healthy individuals, long chain n-3 supplementation clearly lowers levels of serum triglycerides even when no positive effect on glycemia and peripheral glucose utilization were seen (Vessby *et al.,* 2001). Sevak *et al.* (1994) have been reported that South Asians consumed significantly lower n-3 PUFA (0·08 v. 0·13% energy, respectively; P¼0·02), but higher n-6 PUFA (5·4 v. 5·0% energy, respectively; P¼0·05) than white Caucasians in the UK. Lovegrove *et al.* (2004) have also reported similar findings, in addition to a significantly higher dietary n-6 : n-3 PUFA ratio in diets of Indo-Asian Sikhs in the UK as compared with white Caucasians (11·2 v. 6·7, respectively; P,0·001). Furthermore, these investigators have shown that South Asians had a higher proportion of total fatty acids as n-6 PUFA and a lower proportion of long-chain n-3 PUFA in plasma and cellular membrane phospholipids as compared with white Caucasians (Lovegrove *et al.,* 2004). While this could be due to dietary imbalance, low activities of d-5- and d-6-desaturases necessary for the formation of long-chain n-3 PUFA and/or the presence of certain dietary factors that interfere with the formation of EPA and DHA could be other explanations (Das, 2002).

It has been suggested that an imbalance in dietary n-6 and n-3 PUFA may be important for the development of insulin resistance and dyslipidemia in South Asians (Ghafoorunissa, 1998). A low intake of n-3 PUFA, a low energy intake of n-6 and a low n-6 : n-3 PUFA ratio (1·9–2·1), which was much lower than the recommended ratio in Asian Indians belonging to the low socio-economic stratum in North India (Misra *et al.,* 2001). Furthermore, this underprivileged population had a high prevalence of insulin resistance, dyslipidemia, hypertension and T2DM ((Misra *et al.,* 2002). In adolescent and young Asian Indians, it has been recently shown that the mean percentage of energy intake contributed by PUFA was significantly higher in those with fasting hyperinsulinaemia as compared with those with normal insulin levels (9·2 %, P¼0·021). However, the percentage energy contribution of n-3 PUFA and n-6 PUFA in the hyperinsulinaemic (0·8 and 4·8%, respectively) and normoinsulinaemic groups (0·7 and 4·2%, respectively) was similar. An important observation was that a higher intake of PUFA was associated with higher fasting serum insulin levels (OR 2·2). Specifically, n-6 PUFA intake was a significant independent predictor of fasting hyperinsulinaemia. In view of these observations in Indian adolescents and young adults, it would be prudent to restrict the intake of n-6 PUFA. Importantly, the role of n-6 PUFA in the pathogenesis of insulin resistance in Asian Indians needs to be investigated further (Isharwal *et al.,* 2008).

Intervention studies with n-3 PUFA have not yielded encouraging results among South

Asians. Lovegrove *et al.* (2004) compared the impact of long-chain n-3 PUFA supplementation in white Caucasians and Indo-Asian Sikhs in the UK. These investigators showed that with supplementation, concentrations of plasma TAG, apo B-48, platelet phospholipids and arachidonic acid decreased, and HDL-cholesterol, platelet phospholipids, EPA and DHA significantly increased in Indo-Asians; however, no effect on insulin sensitivity was seen (Lovegrove *et al.,* 2004). In another study, Brady *et al.* (Brady, 2004) reported the TAG lowering effect of fish-oil supplementation against a background of high or moderate intake of n-6 PUFA in Indian Asians in the UK. Further, in line with the study of Lovegrove *et al.* (2004), long-chain n-3 PUFA supplementation, whether given in combination with a background dietary intake of high or moderate n-6 PUFA, had no effect on insulin sensitivity in Indo-Asians. In yet another study by this group, no effect of a high or moderate n-6 : n-3 PUFA ratio diet on clinically relevant insulin sensitivity and dyslipidaemia was reported in Indian Asians in the UK. However, there was a trend towards a loss of insulin sensitivity on the high-n-6 : n-3 PUFA diet, and lower EPA and DHA levels were observed following the high-n-6 : n-3 PUFA diet (Minihane *et al.,* 2005).

Low intakes of n-3 PUFA in Asian Indians could be due to the vegetarian status. Even in those individuals who are nonvegetarians, fish intake is inadequate. Interestingly, those living in the coastal area of India and having high fish intake have a better lipid profile, specifically low serum TAG levels (Bulliyya, 2000; Bulliyya *et al.,* 1994). In vegetarian Asian Indians, a higher intake of n-3 PUFA could be achieved by the addition of several low-cost vegetarian dietary items containing n-3 PUFA, for example, green leafy vegetables, rajmah (kidney beans), bajra (Sorghum vulgare) and chana (black gram). These food items are widely available at low cost in India.

Dietary monounsaturated fatty acids (MUFA)

A MUFA-enriched diet resulted in significant increases in insulin sensitivity with modest total fat intake in healthy subjects (Vessby *et al.,* 2001). Further, MUFA-rich diets lowered mean plasma glucose and plasma TAG levels and reduced insulin requirements in patients with T2DM (Garg, 1998; Garg *et al.,*1988). Improvement of lipoprotein and glycaemic profiles with a high-MUFA diet may not be related to changes in insulin sensitivity but could be due to a reduction in the dietary carbohydrate load (Garg, 1998). The increase in insulin sensitivity induced by MUFA-rich diets may be due to their effect on gastric emptying and increased basal glucose uptake (Dimopoulos *et al.,* 2006). Overall, high-MUFA diets have shown beneficial effects in T2DM, but their influence on insulin resistance, although appearing beneficial, is still inconclusive. Sevak *et al.* (1994) has been shown a lower dietary intake of MUFA (% of energy) in South Asians as compared with white Caucasians (11·9 v. 14·7, respectively; P,0·001) in the UK. In a relatively recent study on Indian Asians living in the UK, the mean MUFA intake in subjects with a highn- 6 : n-3 PUFA diet was 25 g/d, while in those consuming a moderate-n-6 : n-3 PUFA diet, MUFA intake was 43 g/d (Minihane *et al.,* 2005). Asian Indians belonging to the low socio-economic stratum in India consumed low MUFA (% of energy): males, 4·7%; females, 5·7% (Misra *et al.,* 2001). Non-significantly higher MUFA intake (% energy) was seen in hyperinsulinaemic adolescents and young adults in India than those with normal fasting plasma insulin levels (7·4 v. 6·9, respectively; P¼0·26) (Isharwal *et al.,* 2008). A study of adult urban males from three different states in India (North India, Uttar Pradesh; South India, Goa; West India, Kolkata) showed low MUFA intake (Udipi *et al.,* 2006). In North India (Rajasthan), the daily intake of MUFA (% energy) was higher in illiterate individuals than in educated individuals (15·6 v. 8·6, respectively; P,0·05) (Singhal *et al.,*1998). In South India, however, the middle income group consumed higher MUFA (11·9 g/d) as compared with the low income group (8·5 g/d) and a low intake of MUFA (4% energy) has been reported in an urban slum population (19–49 years) in New Delhi (Mohan *et al.,* 2001).

Trans-fatty acids (TFA)

Since saturated fatty acids were found to be bad for you a couple decades ago, the food industry wanted to switch to use of unsaturated fatty acids. Unfortunately, unsaturated fatty acids become rancid relatively quickly. To combat the instability of unsaturated fatty acids, manufacturers began to "hydrogenate" them, a process that makes them more stable. The result was a more solid and longer lasting form of vegetable oil, called "partially hydrogenated" oil. Unfortunately, when unsaturated vegetable fats are subjected to the process of hydrogenation, a new type of fatty acid is formed. This new type of fatty acid is called trans fatty acid (TFA).

Dietary TFA intake has been specifically associated with dyslipidemia and an increased risk of T2DM and CVD (Ascherio *et al.,* 1999; Salmeron *et al.,* 2001). Studies in patients with T2DM have showed an elevated postprandial insulin response with a TFA-rich diet as compared with a cis-MUFA-rich diet (Christiansen *et al.,*1997). However, data regarding the dietary influence of TFA on insulin resistance in healthy subjects are limited. TFA in Indian diets are mostly derived from Vanaspati (hydrogenated oil commonly used as a cooking medium), containing 53% TFA. Since this oil is cheaper than other cooking oils and commonly available even in rural areas, it is widely consumed by individuals belonging to middle and low socio-economic strata. In urban adult slum dwellers belonging to the low socio-economic stratum in New Delhi, TFA, particularly in men, reached 1% of the energy intake, mostly due to the use of Vanaspati oil in cooking (Misra *et al.,* 2001).

Moreover, elevated levels of lipoprotein(a) seen with high TFA intake may be important in Asian Indians who show one of the highest levels of lipoprotein(a), correlating with CVD (Misra *et al.,* 2001, Anand *et al.,* 1998). The effect of TFA is also on the uptake and metabolism of essential fatty acids, adversely leading to their deficiency (Holman and Johnston, 1983). This has important implications as essential fatty acid intake was seen to be already low in Asian Indians (Misra *et al.,* 2001).

Dietary carbohydrates

A high intake of carbohydrate may lead to hyperinsulinemia, high serum TAG and low HDL-cholesterol levels associated with insulin resistance (Borkman *et al.,*1991). Samaha *et al.* (2003) showed that severely obese subjects with a high prevalence of T2DM and related metabolic syndrome lost more weight and had greater improvements in the plasma TAG level and insulin sensitivity on a low-carbohydrate diet than those on a low-fat diet. Other dietary modifications, such as low-glycaemic index food and increasing fibre intake, can help to limit the untoward metabolic consequences of the low-fat high-carbohydrate diets.

In a comparative study, Burden *et al.* (1994) have reported higher carbohydrate content (% energy) in an Asian meal (45%) than in a European meal (25%). Others have supported this view (Greenhalgh, 1997; Misra and Vikram, 2004). Further, several investigators have shown that Asian Indians in India consume relatively more carbohydrates (% energy) (about 60–67%) (Misra *et al.,* 2001; Devi *et al.,* 2003; Shobana *et al.,* 1998) as compared with the migrant South Asians (North Indians and Pakistani Sikhs) in the UK (about 46%) (Sevak *et al.,* 1994) and Asian Indians and Pakistanis in the USA (about 56–58%) (Yagalla *et al.,* 1996; Misra and Vikram, 2004; Kamath *et al.,* 1999). In a study on South Asians in the UK, a 'typical' Asian Indian vegetarian diet as compared with a 'typical' European diet induced higher and more prolonged rises in mean plasma glucose levels (5·29 v. 4·32 mmol/l, respectively; P,0·02) and higher 2 h postprandial insulin levels (mean 28·2 v. 8·1 mU/l; P,0·02). Sevak *et al.* (1994) showed that the total carbohydrate and sucrose contents of the diets were positively correlated with postprandial hyperinsulinaemia in South Asians residing in the UK. Yagalla *et al.* (1996) studied the nutrient profile of US-based Asian Indians and reported that increased carbohydrate intake (above the threshold of total carbohydrate intake of 282 g/d) in them resulted in high serum TAG, particularly in insulin resistant subjects. Even in Asian Indians belonging to the low socio-economic stratum living in urban slums, a higher percentage of energy from carbohydrate intake was positively correlated with serum TAG levels (Misra *et al.,* 2001). The consumption of large carbohydrate meals is very common in Asian Indians, especially at dinner time. This led to hyperinsulinaemia and also causes postprandial hyperglycaemia and hypertriacylglycerolaemia. Therefore, a rational strategy would be to distribute carbohydrate evenly through three to five meals per day, especially in patients with diabetes, so as to avoid high carbohydrate loading in a short time in the day.

Dietary fibre

Evidence from epidemiological studies supports the beneficial effects of high intakes of fruits and vegetables, with possible reductions of over 80% in CHD, 70% in stroke and 90% in T2DM by following Mediterranean diets, which are low in energy and high in fibre (Willett, 2006). Higher intakes of fruit and vegetables have been shown to lower the risk of the metabolic syndrome (Esmaillzadeh *et al.,* 2006). Few studies in India have reported data on fibre intake; however, methodologies of analysis of fibre intake have differed. Poor intake of fruit and vegetables resulting in low fibre intake was reported in less educated urban Asian Indians in North India (Singhal *et al.,* 1998), in subjects residing in West Bengal, India (reported as crude fibre intake; 5·7 g/d) (Mitra *et al.,* 2004) and in an urban slum population in North India (reported as crude fibre intake; males, 8·5 g/d; females, 4·1 g/d) (Misra *et al.,* 2001). In a recent study on adolescents and young adults from North India, crude dietary fibre consumption is 8·6 g daily (Isharwal *et al.,* 2008). Fibre intake may also depend on socio-economic stratum and ability to buy relatively expersive fruits and vegetables, being higher in the middle income group (8·6 g/d) v. the low income group (4·7 g/d) (Mohan *et al.,* 2001). Many studies in rural populations in India (Pushpamma *et al.,* 1982), including a subset of rural pregnant women (Panwar and Punia, 1998), have shown a poor intake of fruits and vegetables. Even in migrant Asian Indians or South Asians, fibre intake has been reported to be low, particularly in vegetarians; however, it varied by region of origin in India and dietary profile of the migrants from India and other South Asian countries (Jonnalagadda and Diwan, 2002). Intervention with high-fibre diets in Asian Indians has been poorly investigated. Mean blood glucose values in North Indian subjects residing in the UK after a high-fibre (32 g/d) mixed meal was lower than after the standard glucose load. According to the authors, these findings suggest the potential of high-fibre constituents of a typical North Indian diet in improving glucose tolerance (Bhatnagar, 1988). Clearly, more data are needed from South Asians in this area of nutrition. Table 1 presents principles of a low-fat, nutrient dense plant based diet for the management of diabetes

Micronutrients and trace elements

Trace elements (micronutrients) such as Mg^{2+} have been postulated to play a role in glucose homeostasis and insulin action (Saris *et al.,* 2000; Barbagallo *et al.,* 2003). Some investigators have shown that dietary fibre and Mg^{2+} explain most of the beneficial effect of whole grains on insulin sensitivity (Liese *et al.,* 2003; Meyer *et* .

al. 2000; Fung *et al.,* 2002). In this context, it is important to note that both Mg and Ca intakes were significantly lower for the Asian

Indian vegetarians than for the white Caucasian vegetarians (Kelsay *et al.,* 1988). Vitamin D and Ca intakes were less than two-thirds of the recommended intake in Gujarati Asian Indian migrants in the USA, and BMI was negatively correlated with Ca intake (Jonnalagadda and Khosla, 2007). Nearly 95% of ethnic South Asians in the UK, whose random blood glucose level indicated 'high risk' of diabetes, had vitamin D deficiency (Boucher *et al.,*1995). Effect of nutrition during the perinatal period and early childhood on insulin resistance in adulthood has been reported. Among Asian Indian mothers residing especially in the rural areas in India consume lower energy (approximately 7·53 v. 10·04 MJ, respectively) and protein (45 v. 90 g/d, respectively) but higher percentage energy from carbohydrates (72 v. 50 %, respectively) as compared with British mothers (Rao *et al.,* 2001). Such inadequate maternal dietary intake during intra-uterine fetal development leads to fetal undernutrition and smaller neonatal size. Further, some evidence exists that there is an increased susceptibility of low birth weight babies to develop insulin resistance, hypertension and CVD in adult life. Some scientists believe that widespread maternal undernutrition has contributed to the raise of diabetes into an epidemic level in Asian countries, and is supported by the fact that more than half of low-birth-weight babies are South-east Asians (UNICEF, 2002). This line of thought appears to be an oversimplified explanation to diseases; those have much more complex causation. At the same time, it is interesting to note that better nourished and heavier urban Asian Indian babies (mean weight 2·9 kg) have an almost five times higher susceptibility to T2DM as compared with rural babies (mean weight, 2·6 kg) (Yajnik, 2004), implicating overriding roles of dietary excess and lifestyle factors. Indeed, the evidence now suggests that those who have a low birth weight have an increased tendency to develop hyperglycaemia only when fed excess energy and those who have increased rate of weight gain and adiposity in childhood (Bhargava *et al.,* 2004; Sachdev *et al.,* 2005). The focus is gradually shifting to micronutrient deficiencies in maternal diets and their relationship to insulin resistance in children and adults. It is important to note that the intake of most vitamins and minerals, particularly vitamin D, total folate, vitamin B6 and Mg^{2+}, were lower in pregnant Asian Indian women in the UK as compared with the intakes of most nutrients consumed by pregnant European women (Eaton *et al.,* 1984). Interestingly, in a recent study in women residing in west India, high maternal erythrocyte folate concentrations predicted greater adiposity and higher insulin resistance, and low vitamin B12 levels predicted higher insulin resistance in offspring (Yajnik *et al.,* 2008). Maternal nutrition during pregnancy, both macronutrients as well as micronutrients, in rural Indians has been reported to affect fetal growth, body composition and disease risk in adulthood (Rao *et al.,* 2001). Overall, both maternal undernutrition and excess nutrition in children appear to be important in the development of adiposity, insulin resistance and related diseases in childhood and adults; however, it would be premature to implicate any specific micronutrient. The preventive implications on components of the metabolic syndrome would involve better fetal growth through improved maternal nutrition and reducing over-nutrition in the early years of life.

Dietary patterns and socio-economic status in Asian Indians and the insulin resistance syndrome

In South India, individuals belonging to the middle income group (most having a sedentary job profile, average monthly income 8075 rupees consumed significantly higher amounts of energy (7853 v. 6577 kJ; 1877 v. 1572 kcal), total fat (60·7 v. 32·3 g/d), SFA (15·9 v. 11·3 g/d) and sugar (73·1 v. 43·8 g/d) as compared with the low income group (most in labour-intensive jobs, average monthly income 1400 rupees (Jonnalagadda and Khosla , 2007). Further, age-standardised prevalence rates of obesity, impaired glucose tolerance, T2DM, hypertension, dyslipidaemia and CVD were significantly higher in the middle income group as compared with the low income group (Mohan *et al.,* 2001). Along with imbalanced dietary intake, including low intakes of MUFA, n-3 PUFA and fibre and a high intake of SFA, the urban slum dwellers (low socio-economic stratum, 90% having monthly income) (Misra *et al., 2001;* Misra *et al.,* 2001) in North India showed a high prevalence of abdominal obesity, hypercholesterolaemia, hypertriacylglycerolaemia and T2DM and low levels of HDL-cholesterol (Misra *et al.,* 2001). Interestingly, one study has shown a higher intake of total energy and SFA in rural v. urban subjects; however, the prevalence of CVD and hypercholesterolaemia was higher in urban subjects and hypertriacylglycerolaemia and low levels of HDL was seen more in rural subjects (Chadha *et al.,* 1997). A recent study by Goyal *et al.* (2010) suggested that the prevalence of overweight and obesity in children varies remarkably with different socioeconomic development levels. The prevalence of overweight among children was found to be higher in middle socioeconomic status (SES) as compared to high SES group in both boys and girls whereas the prevalence of obesity was higher in high SES group as compared to middle SES group. The prevalence of obesity as well as overweight in low SES group was the lowest as compared to other group. Eating habit like junk food, chocolate, eating outside at weekend and physical activity like exercise, sports, sleeping habit in afternoon having remarkable effect on prevalence on overweight and obesity among middle to high SES group. Family history of diabetes and obesity were also found to be positively associated. Recent data show that the prevalence of dyslipidaemia, obesity and other metabolic syndromes in rural areas of India is increasing. A study of the rural population of Andhra Pradesh (Central India) showed that 18·4% of men and 26·3% of women were overweight, and 26·9% of men and 18·4% of women had metabolic syndromes (Chow *et al.*, 2008). A study by Kinra *et al.* (2010) suggested that risk factors for dyslipidemia and obesity are generally more prevalent in villagers of south India compared with villagers of north India. They showed that the prevalence of dyslipidaemia is 21% (17% to 33%) in north Indian men compared with 33% (29% to 38%) in south Indian men, while the prevalence of obesity was 13% (9% to 17%) in north Indian women compared with 24% (19% to 30%) in south Indian women.

Avoid animal products	Animal products (meat, dairy products, and eggs) typically contain significant amounts of saturated fat and cholesterol. They also contain animal protein and lack fiber and healthful complex carbohydrates.
Avoid added vegetable oils and other high-fat foods	All fats and oils are highly concentrated in calories: 1 g contains 9 calories, compared with only 4 calories for 1 g of carbohydrate. It is helpful to avoid foods fried in oil limit nuts, and peanut butter. Aim for total calories from fat to equal approximately 10% of caloric intake (for example, the person who consumes about 1800 calories daily would aim for 20 g of total fat/day). Flax seeds, soy beans, and small amounts of walnuts are good sources of omega-3 fatty acids.
Choose low glycemic index foods	The glycemic index (GI) measures the glucose response to single foods effect on blood glucose levels. High glycemic index foods cause a greater blood-glucose response and may also contribute to higher triglyceride levels. It is not necessary to know the glycemic index of every carbohydrate-containing food; a general awareness that white sugar, flour, and some breads are typically high, while beans, oatmeal, brown rice and other unprocessed grains, sweet potatoes, and most fruits and vegetables are useful.
Go high-fiber	It is helpful to aim for at least 40 grams of fiber each day. Start slowly. Expect a change in bowel habits (usually for the better). Choose beans, vegetables, fruits, and whole grains (eg, whole wheat, barley, oats).
Focus on the “New Four Food Groups”	Enjoy unlimited whole grains, legumes (beans, lentils, peas), fruits, and vegetables.
Nutritional considerations	
Protein	Plant foods provide adequate and high-quality protein, and intentionally combining or complementing proteins is not necessary. The recommended amount of protein in the diet for most adults is 10 to 15 percent of calories. Meals providing a variety of vegetables, legumes, and grains typically contain this amount or more. If extra protein is desired, choose more beans.
Calcium	Good calcium sources include green vegetables (eg, broccoli, kale, collards, mustard greens), beans, figs, fortified juices and cereals, and fortified soy or rice milks. Walking and other weight-bearing exercise also help to strengthen bones.
Vitamin D	The body's use of calcium is controlled by vitamin D. Short amounts of sun exposure a few days a week provide enough vitamin D, but deficiency is fairly common, especially in northern States. Specific recommendations for the amount of vitamin D for people with diabetes, with or without deficiency, have yet to be determined. The 400 IU in a multivitamin may prevent deficiency.
Vitamin B12	It is important to have a reliable source of vitamin B12. Although fortified foods (some brands of breakfast cereals, soymilk, etc) contain B12, a more reliable source is any common multiple vitamin. B12 supplementation is essential for vegans, and a good practice for everyone else, too. Some medications, such as metformin, may interfere with B12 absorption.

Table 1: Principles of a Low-Fat, Nutrient-Dense, Plant-Based Diet for Managing Diabetes

Regional and geographical dietary patterns and habits and insulin resistance

Regional differences in dietary patterns and food habits may have some influence on the occurrence of obesity and hyperglycaemia in Asian Indians. Data from a study carried out nearly 35 years ago show differences in North and South Indian diets (Malhotra, 1973). While South Indians predominantly eat a diet consisting of boiled rice and sambhar (thin lentil soup), use coconut oil in cooking and consume a small quantity of milk, North Indians eat a wheat-based diet, consisting of wheat

	Mean consumption (g/d) CUPS (1997) (n 403)		Mean consumption (g/d) Cures (2005) (n 2042)	
	Mean	**SD**	**Mean**	**SD**
Age (Years)	49	13.0	40.7	12.8
BMI (kg/m2)	21.5	4.3	23.9	4.5
Waist circumference (cm)	69.5	18.4	84.8	12.0
Food groups (g/d)				
Cereals	277.8	100.8	369.0	106.1
Pulses and legumes	29.4	12.3	52.7	20.3
Leafy vegetables	37.0	33.5	38.2	22.3
Other vegetables	113.2	54.4	89.4	25.7
Roots and tubers	54.7	37.9	156.2	76.8
Fruits	50.4	39.0	112.4	42.8
Non-veg (meat, fidh and poltry)	30.9	10.5	83.3	45.4
Visible fats and oils	30.1	10.9	33.6	11.9
Nuts and oilseeds	9.4	7.1	23.0	13.9
Sugars	11.7	6.1	22.8	15.3
Nutrients				
Energy (kcal)	1782	409	2484	561
Energy (kj)	7456	1711	10393	2347
Protein (%E)	11.4	1.2	12.1	1.7
Fat (% E)	29.4	3.9	23.9	4.9
Carbohydrate (%E)	58.2	5.9	63.8	6.6
Dietary fiber (g)	37.0	9.2	34.7	10.3

CUPS, Chennai population study; CURES, Chennai Urban Rural Epidemiological study; percentage of energy.

Table 2: Comparison of urban (Chennai city) dietary intake in the year 1997 (CUPS, n 403) and 2005 (CURES) in the study population aged e” 20 years (n 2042)

chapattis (Indian bread), vegetables cooked with ghee (clarified butter), milk and yoghurt. These authors also showed that North Indians consumed 2700 calories and 150 g fat per d, and South Indians consumed 2400 calories and 12 g fats per d, including mainly seed oils. The higher carbohydrate intake in South Indians v. North Indians was probably due to rice-based diets in the former. In this study, a higher prevalence of T2DM (8·8%) was shown in the South Indians v. the North Indians (2·7%) (Malhotra, 1973). A dietary profile study of urban adult population in South India by Radhika *et al.* (2010) showed that the mean daily energy intake is 10 393 (sd 2347) kJ (male: 10953 (sd 2364) kJ v. female: 9832 (sd 233) kJ). Carbohydrates are the major source of energy (64%), followed by fat (24%) and protein (12%). Refined cereals contributed to the bulk of the energy (45.8%), followed by visible fats and oils (12.4%) and pulses and legumes (7.8%). However, energy supply from sugar and sweetened beverages is within the recommended levels. Intake of micronutrient-rich foods, such as fruit and vegetable consumption (265 g/d), and fish and seafoods (20 g/d), was far below the FAO/WHO recommendation. Dairy and meat products intake was within the national recommended intake. The diet of this urban South Indian population consists mainly of refined cereals with low intake of fish, fruit and vegetables, and all of these could possibly contribute to the risk of non-communicable diseases such as diabetes in this population.

It is important to note that currently, while most traditional South and North Indian families continue to consume diets as above, many young individuals in many parts of India consume a wide variety of diets: North and South Indian, and 'Westernised' diets and snacks, in line with rapid nutrition transition and the increasing presence of aggressive marketing by transnational food companies.

Community lifestyle intervention studies in Asian Indians

Given imbalanced nutrition and the increase in obesity, and T2DM in Asian Indians, community- based non-pharmacological intervention through the promotion of healthy food choices and increase in physical activity are needed. A relative risk reduction of 28·5% (P¼0·018) in cumulative incidences of diabetes through lifestyle and dietary changes, higher than that achieved by metformin alone (26·4 %; P¼0·029), has been shown in South Indian patients (Ramachandran *et al.*, 2006). Improved dietary patterns of individuals with hyperglycaemia, a decrease in obesity, and a reduction of fasting blood glucose levels in adults and adolescents (aged 10–17 years) with pre-diabetes and adults with T2DM by 11, 17 and 25%, respectively, were seen in a South Indian population with dietary interventions. The dietary modifications included: increase in fibre and protein intake from local low-cost resources such as the nutritionally rich drumstick leaves, millets, legumes/lentils and whole grains; avoidance of sweetened drinks; substitution of polished white rice with millets, sprouted legumes and vegetables; reduction of fat content and portion control (Balagopal *et al.,* 2008). Asian Indian migrants in New Zealand also showed a decrease in obesity, blood pressure, and beneficial effects on dyslipidemia but no effect on insulin sensitivity with dietary interventions, which included encouraged use of rapeseed oil, fat removal from meat and increase in fish consumption (Rush *et al.,* 2007).

Increasing prevalence of childhood obesity calls for comprehensive and cost-effective educative measures in India. School-based educative programmes can greatly influence children's behaviour towards healthy living. A improvement in nutrition-related knowledge and behaviour of urban Asian Indian school childrenhas been reported in 'Medical education for children/Adolescents for Realistic prevention of obesity and diabetes and for healthy aGeing' (MARG) intervention study (Shah *et al.,* 2010).

Conliusion

Dietary factors are likely to have greater and often overriding influence in the development of insulin resistance, and T2DM in Asian Indians and South Asians than genetic factors. Several studies in Asian Indians have established the link between dietary nutrients and insulin resistance. Higher intakes of carbohydrate, SFA, TFA and n-6 PUFA, and lower intakes of n-3 PUFA and fibre, and a higher n-3 : n-6 PUFA ratio have been reported in Asian Indians, as compared with other populations. Intervention studies with n-3 PUFA increased the EPA and DHA content of membrane phospholipids, improved lipid profile but did not show a beneficial effect on insulin resistance. Further, high dietary n-6 PUFA and SFA are significant independent predictors of fasting hyperinsulinaemia and high levels of C-reactive protein, respectively, in adolescent Asian Indians. Asian Indians consume large carbohydrate meals, which may lead to high concentrations of plasma TAG, increased levels of LDL-C decreased levels of HDL-C and also cause postprandial hyperinsulinaemia. High sucrose/fructose diet increase body weight, and risk for T2DM, and may have deleterious effect on insulin sensitivity. Genetic predisposition, dietary habits, rapidly changing lifestyle, physical inactivity and migration are contributory factors for high prevalence of insulin resistance in Asian Indians. Maternal and fetal undernutrition (which are very common in India) and excess adiposity in early childhood increase the risk of hyperglycemia and insulin resistance later in life. There is urgent need of programmes to be initiated for the awareness and prevention of childhood obesity. Dietary modifications advised include: reduction in fried snacks, commercial/fast foods containing TFA, polished rice, refined carbohydrate flour (by using whole grains and mixing protein and fibre-based flour such as Bengal/black gram flour and bajra (*Sorghum vulgare*); promotion of fruit and vegetable intake; replacing aerated/sweetened fruit drinks with healthy alternatives such as lemonade and skimmed buttermilk. These dietary changes should be emphasized through lectures and printed leaflets, and through involvement of students in debates, skits and cookery contests.

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