

## REVIEW ARTICLE



## Challenges in Nutrition

# Heterogeneity of Dietary practices in India: current status and implications for the prevention and control of type 2 diabetes

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Diet is one of the important modifiable factors in prevention of type 2 diabetes (T2D), making it important to understand geographical variations of food consumption pattern, their similarities and differences across various regions. Asian Indian diet patterns are mostly carbohydrate-based and with vast regional diversity. Staple food, food groups consumed, meat consumption pattern, type of fermented foods, food preparations, type of cooking oil used and food ingredients vary with different regions of India. There has been a slow transition from consumption of coarse grains to refined grains owing to socio-economic, cultural and other factors. Consumption of fruits and vegetables, fats, ready-to-eat foods and sugar is higher in urban population whereas consumption of carbohydrates in the form of cereals and millets is higher among the rural population. Cereal grains followed by pulses and legumes are main sources of protein, given that the frequency of meat consumption is low even among non-vegetarians in India compared to other countries. Overall, there is a tendency towards consumption of calorie-dense foods at the cost of food diversity, which may also result in micronutrient deficiencies as well as development of T2D and related metabolic diseases. Public health strategies and policy level decisions involving stakeholders with diet and lifestyle modification as focal points are absolute priorities to prevent and manage the burden of obesity and T2D in India.

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**BACKGROUND**

Diabetes is rapidly increasing in India, requiring a critical look at changing lifestyle practices. Among them diet remains the most important determinant [1]. Dietary practices in India are influenced by cultural and geographic factors. Besides heterogeneity in diets, regional variations in cooking practices and mediums are observed [2]. Distinct plant-based dietary patterns are dominant in India while animal-based dietary patterns (lacto/ovo/lacto-ovo vegetarian, pescatarian and non-vegetarian) are influenced by religion and culture [2, 3]. Other socio-economic factors like religion, family size, family income and social class have also been found to contribute to the diversity [4]. Addressing the heterogeneity in Indian scenario is crucial to identify modifiable dietary risk factors for the prevention of Type 2 Diabetes (T2D) and associated perturbations.

In this review, an attempt has been made to study the differences in Indian foods consumed across various regions. Literature search was carried out in PubMed using the key words "(consum\* OR intake) AND (carbohydrate\* OR protein OR fat OR fibre OR oil OR salt OR sugar OR meat OR fruit\* OR vegetable\*)" combined with "((rural OR urban) OR (north\* OR south\* OR east\* OR west\* OR north-east OR centr\* OR region)) AND (India)" resulting in 3743 initial articles. Search was further limited to

English language and a time period from 2000 to 2021, resulting in 1973 articles. Screening for title and abstract resulted in 187 articles and full text screening resulted in 43 articles. Manual searching was also done in other databases in which 15 relevant articles were found. Finally, 58 articles were included in the review. This article is presented in three sections as follows

- (I) Traditional foods in India and dietary pattern across regions
- (II) Macronutrient intake among Indians
- (III) Implications of Indian diets for obesity, diabetes and cardiovascular diseases and approaches for prevention.

**TRADITIONAL DIETARY HABITS**

During ancient and medieval times, people in India consumed one or two meals a day majorly comprising of indigestible carbohydrates [5]. A shift from consumption of coarse grains to rice and wheat along with increased fat consumption ensued in the second half of the 20<sup>th</sup> century [6]. Usual composition of a meal in India is a combination of cereals and pulse-based preparations [7]. Food historians have recorded more than 50 types of pulses in various forms; lentils, chickpeas, beans and peas being some of

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the common ones [8]. Pulses and legumes become the second major source of protein after cereal as the daily consumption of meat is relatively low in India [9–12]. Consumption of some meats

(beef and pork) are directed by religious preferences. Chicken, especially native breeds, is the most commonly consumed meat [13]. Consumption of fish and fish products are higher in the States and Union territories along the coastal regions [14]. Dairy products such as butter, yoghurt and buttermilk are commonly used in all regions [2]. Present day full-course meal, known as *Thalis* (term refers to metal plate on which all food items are placed; refer Table S1 for description of foods), provide about 1100–1400 kcal energy, 25–45 g protein, 25–60 g fat, 50–280 mg calcium and 8–25 mg iron regardless of the region [15].

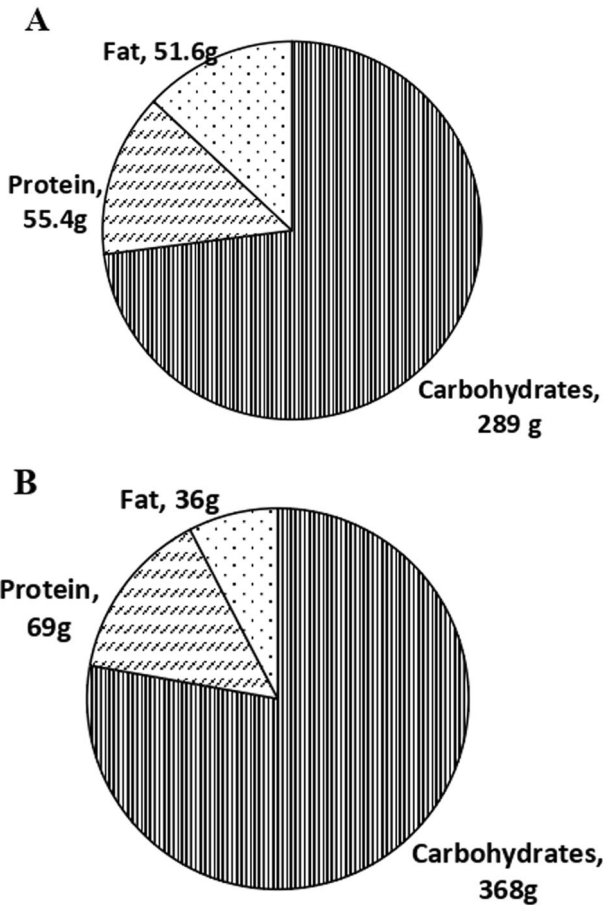
Culturally specific dietary practices commonly include fasting. It is followed either several days in a row for specific festivals or a day-long fasting on particular days. Special occasions and festivals in India involve a huge feast with high calorie meals and sweets made with sugar and *ghee* (clarified butter) throughout the country [16].

**Regional variations in the dietary pattern**

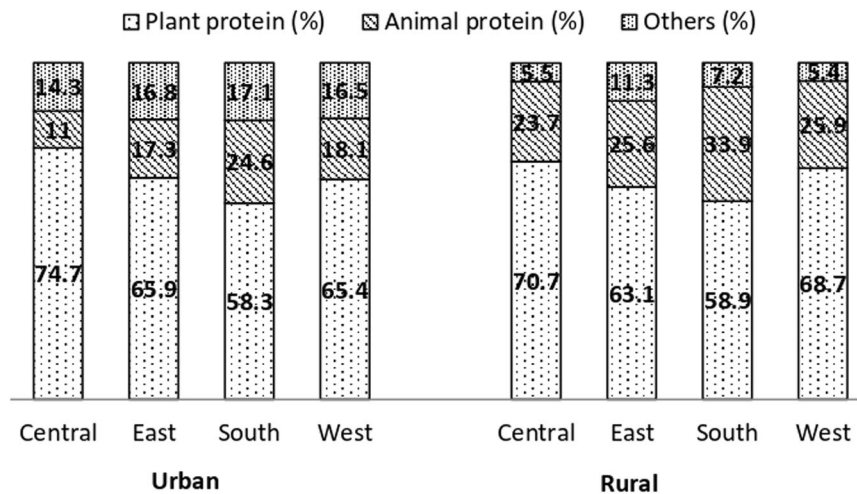
The following is a summary of regional similarities and differences in food consumption pattern in various regions of India.

*Comparison between rural and urban populations.*

- (i) Consumption of carbohydrates is significantly higher in rural areas than the urban, 80.3% of carbohydrates is contributed by cereals (rice and wheat) and millets. Figure 1A and B shows the carbohydrate consumption of urban and rural India, which were 289 g/day and 368 g/day. Major sources of carbohydrates in urban areas are cereals and millets (73.4%) followed by processed foods (10.7%) [17].
- (ii) Fat intake is higher in urban (51.6 g/day) than in rural (36 g/day) areas. Fat consumption is the highest in Northern urban population (24%) compared to the urban areas of other regions [17]. The consumption of animal proteins is higher in rural than in urban (Fig. 2). The pattern of high total energy and fat intake similar to urban populations has been shown in rural to urban migrants compared to the rural populations [18].
- (iii) Expenditure-based food diversity is high in rural areas of coastal and western India [4].
- (iv) Consumption of fruits and vegetables (FV) has been observed to be lower in rural population compared to the



**Fig. 1** **Macronutrient consumption pattern among Indian adults.** **A** Per day consumption of macronutrients in grams in urban Indian adults; **B** Per day consumption of macronutrients in grams among rural Indian adults [17].



**Fig. 2** **Sources of protein (in percentage) in different regions among rural and urban Indian adults.** Plant protein: Cereals, millets, pulses, legumes, nuts and oilseeds; Animal proteins: Milk and milk products, meat, poultry, fish and sea foods; Others: Processed foods. (Source: ‘What India Eats’ [17]).

**Table 1.** Region-wise dietary practices, macronutrient intake and prevalence of diabetes across India.

India (28 regions)		Staple—food ingredient <sup>a</sup>	Dietary pattern <sup>b</sup>	Mean macronutrients intake per day <sup>c</sup>			Prevalence of diabetes (%) <sup>c</sup>
				CHO (g)	Protein (g)	Fat (g)	
South	Urban	Rice	Rice Millets Dairy products Fruits Vegetables Snacks Meat	298	59	50	29
	Rural	Rice		361	64	34	10
North	Urban	Wheat	Pulses Dairy products Fruits Vegetables Snacks	221	47	67	28
North East	Urban	Rice	Cereals Millets Pulses Meat Dairy products Vegetables Fruits	457	87	62	26
Central	Urban	Wheat	Cereals Millets Pulses Meat Dairy products Vegetables Fruits	277	50	50	18
	Rural			400	85	36	5
East	Urban	Cereal-based diets High intake of simple CHO like Rice Fish and Meat	Cereals Pulses Fish Root vegetables Fruits Dairy products Snacks and sweets	323	58	43	19
	Rural	Cereal-based diets Fish and Meat		384	59	23	4
West	Urban	Wheat Pulse	Rice, pulse, sweets, snacks, fruits, wheat, dairy products, sprouts, millets, leafy vegetables, sorghum	241	48	57	24
	Rural	Wheat Pulse		336	70	43	8

Numerical values have been rounded off to the nearest number.

CHO carbohydrates, g gram, % percentage.

<sup>a</sup>Adapted from 'Dietary transition in India: temporal and regional trends, 1993–2012' [80].

<sup>b</sup>Adapted from 'Dietary patterns in India: a systematic review' [81].

<sup>c</sup>Adapted from 'What India Eats' [17].

urban and peri-urban populations [19]. Low fruit consumption has been observed among urban population with metabolic syndrome (65%) in Eastern India [20]. Vegetable consumption is less in Central, Western and Northern rural areas [4]. Per-capita household vegetable consumption was 145 g for rural and 155 g for urban while that of fruits was 15 g and 29 g, respectively [21]. The dietary pattern of rural-urban migrants exhibited resemblance to the urban with about 80% higher consumption of FV [18].

(v) Ready-to-eat foods such as chips, biscuits, chocolates, sweets and juices contributed to about 11.1% and 4.1% of energy in urban and rural areas, respectively, indicating higher calorie-dense 'junk food' consumption in urban

India [17]. About 35% higher consumption of sugar was observed in the rural-urban migrants in comparison with their rural counterparts [18].

(vi) Economic factors influence the energy intake in population; affluent people of both urban and rural areas consumed as high as 3000 kcal/day, double that of their underprivileged counterparts [22]. The variations in the consumption of food groups in different regions, between rural and urban and the prevalence of diabetes are enumerated in Tables 1 and 2.

*Northern and central regions.* Population residing in Northern and Central India consume wheat as their staple cereal [2].

**Table 2.** Dietary practices and prevalence of diabetes across urban and rural India.

Pan India (Region)	Staple food ingredients <sup>a</sup>	Food groups	Intake (g)	Mean macronutrients intake per day <sup>b</sup>			Prevalence of diabetes (%) <sup>b</sup>
				CHO (g)	Protein (g)	Fat (g)	
Urban	Rice and wheat	Cereals and millets	293	212	26	3	25
		Pulses and legumes	39	19	8	1	
		Vegetables	92	4	2	0	
		Roots and tubers	88	11	1	0	
		Fruits	52	4	1	0	
		Fats and edible oils	30	0	0	30	
		Meat, poultry, fish and sea foods	32	0	6	2	
		Milk and milk products	121	8	4	6	
		Nuts and oil seeds	9	1	1	4	
		Miscellaneous	116	31	6	6	
Rural	Cereals and millets	Cereals and millets	394	295	33	4	7
		Pulses and legumes	43	24	10	1	
		Vegetables	80	5	2	0	
		Roots and tubers	74	14	1	0	
		Fruits	47	4	0	0	
		Fats and edible oils	16	0	0	16	
		Meat, poultry, fish and sea foods	75	1	16	3	
		Milk and milk products	118	6	4	5	
		Nuts and oil seeds	13	2	1	5	
		Miscellaneous	40	17	2	1	

Numerical values have been rounded off to the nearest number.

CHO carbohydrates, g gram, % percentage.

<sup>a</sup>Adapted from 'Dietary transition in India: temporal and regional trends, 1993–2012' [80].

<sup>b</sup>Adapted from 'What India Eats' [17].

Cuisines in central India has influence from neighboring regions such as the Northern, Eastern and the Southern cuisines. Wheat preparations (flat breads) like *roti* and *chapati* (flat wheat bread) are the main dish accompanied by *dhal* (cooked pulse preparation), paneer, vegetable or green leafy vegetable preparations e.g. *makki di roti* (unleavened bread prepared from maize flour) prepared in a tandoor and *aloo ka paratha* (wheat flour-based pancake prepared with potato stuffing and clarified butter, served hot with butter) are served hot with accompaniments like *sarson ka saag* (curry made from mustard leaves and spinach), *dhal makhani* (curry made from whole black gram or kidney bean seasoned with clarified butter), etc. Lamb is commonly consumed in Kashmir, whereas chicken is preferred to lamb in other northern and central states. *Lassi* is a traditional, curd based sweetened beverage from Punjab. Rajasthan has a rich cuisine using a variety of *dhals*; many of the dishes are based on millets and milk, due to water scarcity [2, 23]. Traditional foods of Himachal Pradesh, use distinctive food ingredients native to the hills of western Himalayas [24]. *Ghee* is used abundantly in meal preparations all over the northern region [25]. Temple offerings '*Prasad*' are made of high amount of sugar, *ghee*, flour and refined grains indicating high saturated fat and sugar content [26, 27].

In the northern region, the total daily average consumption is as follows; Total energy intake (TEI) being 1723 Kcal/d, carbohydrates, 221 g/day and protein, 47 g/day. 8% of TEI from protein (plant and

animal sources), <3% of TEI from FV and 0.3% of TEI from nuts and oil seeds, which is substantially lower than the recommended intake [17]. Highest intake of protein per day was observed in Central India (48.6 g/day) of all regions [17]. The main source of protein has been cereals and millets contributing to 58.8% and 57.3% of the total protein intake in urban and rural population, respectively.

**Southern region.** Southern parts of India traditionally consume millets and rice [2]. Rice is consumed with *sambhar* (pulse-based stew) or similar stew preparations [7]. Millets and Sorghum are staple dietary articles in the state of Karnataka, and a small amounts of meat/fish/vegetables are added to the cereal preparation to provide variety in taste and texture. Red rice (*Matta*) is the main cereal used in Kerala. In Tamil Nadu, Andhra Pradesh and Telangana rice is consumed along with *dhal*, vegetables and tamarind-lentil-based broth (*sambhar* and *rasam*). A meal typically ends with curd or buttermilk (*moru/majiga*). *Pazhayadu* is a common rice-based fermented food consumed by people from low socio-economic backgrounds in many parts of Southern India [2, 23, 28].

Protein intake from meat and sea foods is the highest in southern region pan India (28% of total energy consumed). Similarly, invisible fat consumption is the highest in South compared to other regions [17]. Coconut oil and *gingelly*

(sesame) oil are commonly used for cooking purpose [25]. Traditional fermented foods like *Idli* (rice- and lentil-based steamed cake), *dosai* (pancake made from fermented batter of rice and black gram), *adai* (pancake prepared from the fermented batter of rice and pulse) and *ragi hurihittu* (flour prepared from popped finger millet) are commonly consumed [29, 30]. In South India, the combined consumption of FV was 265 g/day whereas the WHO recommendation is 400 g/day (or 5 servings/day), wherein higher consumption being significantly associated with younger age [31]. The average consumption of FV is highest in Chennai compared to other cities of about 4.35 servings/ day [32].

**Western region.** Similar to Northern cuisine, *chapati* and accompaniments are the usual dishes consumed. Consumption of milk and milk products is the highest in the western region [17]. A major proportion of the population in the state of Gujarat are vegetarians (no consumption of animal products except milk and milk products) due to religious influences. The region is known for dishes like *dhokla* (fermented lentil-based, steamed dish), *thepla* (flavoured wheat flatbread) and snacks like *fafda* and *khakra* (wheat/bengal gram flour-based toasted round, flatbread). In Maharashtra millets and sorghum are other staple cereals, chicken is the preferred meat; small amounts of meat/fish/vegetables are added to the cereal preparation to provide variety in taste and texture. *Shrikhand* (made from hung-curd) is a popular sweetened milk product-based accompaniment widely consumed in states of Gujarat and Maharashtra [2, 23]. *Amboli* is a traditional Maharashtra fermented rice and lentil-based thick pancake [29, 30].

**Eastern and North-Eastern regions.** In the Eastern states like Odisha and West Bengal, rice is the staple food, mustard oil is the major cooking oil, the dishes are less spicy and oily. Fish and fish products are extensively used in West Bengal. Bihar is mainly a vegetarian state due to religious beliefs [2, 23]. Highest consumption of FV is found in the East compared to rest of the Indian regions [17]. The average consumption of fruits and vegetables has been lowest in Kolkata among other cities in India with 2.81 servings/day [32]. Traditional fermented foods such as *enduri pitha* (cereal-pulse-based fermented food) and *pakhala* are commonly consumed in Odisha [29, 30].

North-Eastern cuisine is substantially different from the rest of India and consists of soybean, bamboo, tree seeds and other native ingredient-based dishes [33]. Fermented foods are based on cereals, pulses, soybean, fish, bamboo shoots, meat and vegetables e.g. *hawaijar* (fermented soyabean), and *selroti* (fried sweet snack from fermented grains). Traditional foods also include preparation of rice-based products such as *ki kpu* and similar dishes made with millets or barley [34]. Consumption of pulses and legumes is the highest in North-east in comparison to the rest of the nation (15.7%). Percent calorie distribution from different food group, adapted from the report by Hemalatha et al. [17] are presented in Figs. 3 and 4 for each region.

## MACRONUTRIENT INTAKE

National level surveys have captured gradual changes in the consumption of food groups across India over time i.e. considerable increase in the per-capita FV and fat intake have been observed while decrease in carbohydrate and protein intake both in rural and urban, indicating a shift from the traditional ways of dining [35].

### Carbohydrate intake

**Cereals.** India has transitioned from consuming complex carbohydrates such as whole grains, pulses and legumes and green leafy vegetables to simple carbohydrates like polished rice, refined wheat flour and processed foods which are high in glycemic index (GI) [36]. Rice is a staple meal in many parts of the country. Many traditional

rice varieties consumed in India have low to medium GI e.g., aromatic *Basmati* in the North, Black rice in the North-east and *Kattuyanam*, *Red Kavuni* and *Black Kavuni* in the South [37–40]. However, cereals grains predominantly dispensed through public distribution system and consumed by the under privileged population are polished rice and wheat, which result in decreased diet diversity and poor intake of nutrients other than carbohydrates [22].

**Fruits and vegetables.** Inadequate FV consumption has been found across all states in India [22]. Despite the high production rates, consumption of FV have been very low in India, some of the reasons being household income and cost of FV [41, 42]. Notably, a major proportion of the FV consumed by Indians are potatoes and bananas, high in simple carbohydrates [21].

### Protein intake

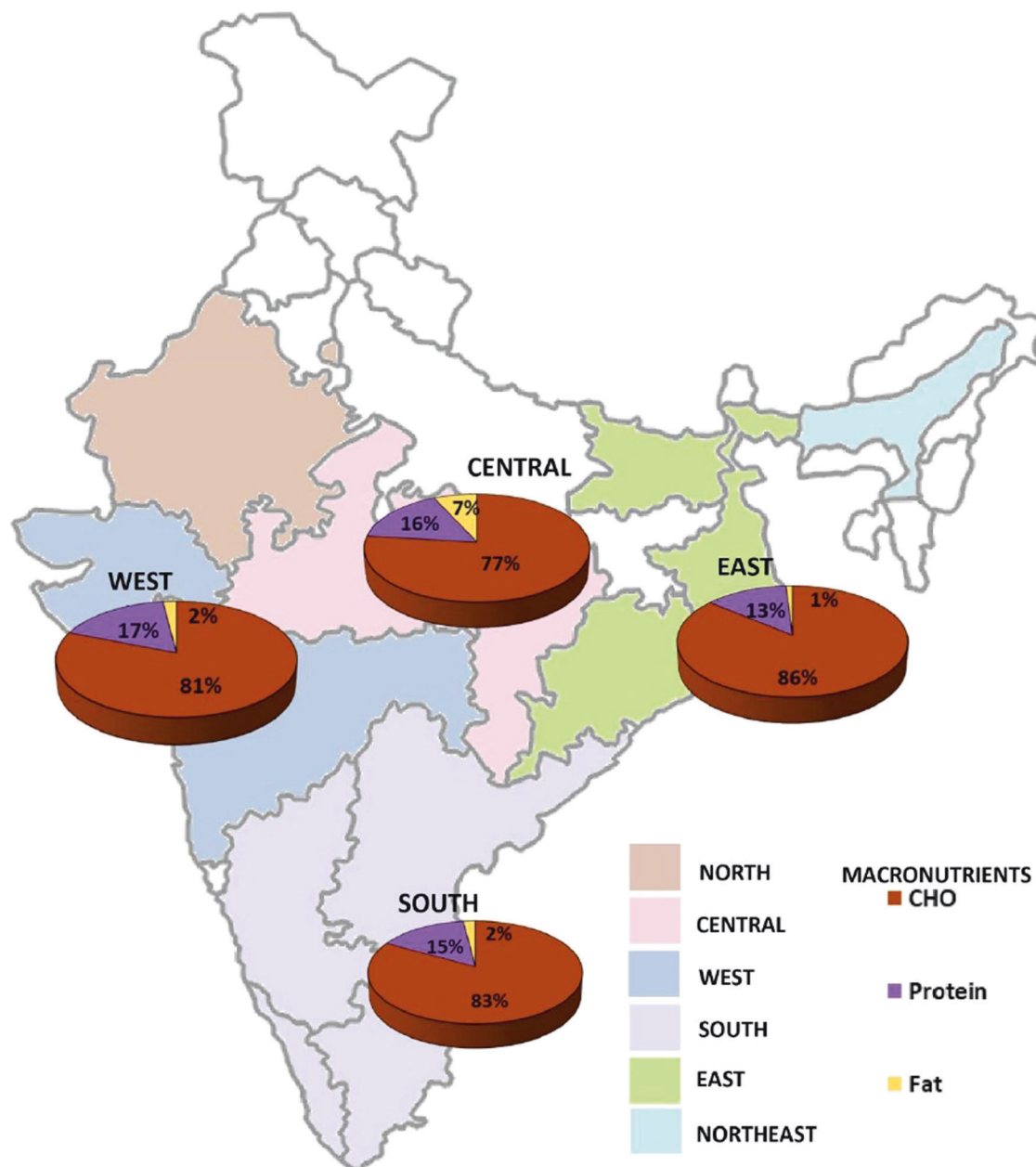
Low protein intake has been consistently reported throughout India, in both rural and urban regions [22]. Currently, protein intake in all regions of India is from plant sources, indicative of poor-quality dietary protein (Fig. 2). There has been a reduction in protein consumption in India over time. Per-capita consumption of pulse and pulse products was higher in urban areas (30.03 g/day) when compared to the rural areas (26.10g/day), however more than 60% of it attributable to the combined intake of various *dals* (dried, split pulses), *arhar* (red gram), *moong* (green gram split) and *urad* (black gram). Notably, increase in the price of milk and its products and chicken was found to be directly proportional to the consumption of pulses [11, 43]. The annual per-capita consumption of meat is less than 5 kg, the lowest in the world and that of fish is 2.85 kg, the lowest among Asian countries [44]. The per-capita consumption of fish along the coastal states and Union Territories have shown a decline from 1983 to 2010 except Kerala and West Bengal [45]. However, poultry consumption has been increasing at a fast pace in India followed by other meat varieties and egg [44].

### Fat intake

Per-capita fat intake has been reported to increase from 31.4 to 41.6 g/day in rural and from 42 to 52.5 g/day in urban Indian population between 1993 and 2012 [43]. Recent NNMB survey revealed that average urban household consumption of fats and oils was exceeding the Recommended Daily Intake by 59.5% [46]. Consumption of saturated fat, butter and *ghee* in patients with hypertension and dyslipidemia were significantly higher in North compared to all other regions [47]. Fast food (“calorie dense food which can be prepared quickly”) consumption has increased across all sections of India, particularly pronounced in adolescents and children indicating an overall increase in the amount of saturated and trans-fat consumption [48]. Per-capita increase in consumption of animal products and oils have been observed in both rural and India [49]. Palm oil, containing high saturated fat content (49 g/100 g) is used in hotels and restaurants extensively due to its relatively lower cost compared to other vegetable oils [50]. Further, reheating of oil is a common practice among small-scale food vendors in India. Interestingly, trans fatty acid content increased significantly in six common Indian fats/oils when subjected to reheating or frying [51]. The consumption pattern of visible and invisible fat is different in urban and rural India, also influenced by the consumption of processed and fast foods (Fig. 5). The increase in total edible oil consumed is higher in urban than in rural area, which may be attributable to socio-economic status and food choices [52].

## IMPLICATIONS OF INDIAN DIETS FOR OBESITY, DIABETES AND CARDIOVASCULAR DISEASES

Previous to 1990s, foods consumed were frugal, whole grains and millets (both rice and wheat) with high fibre, along with

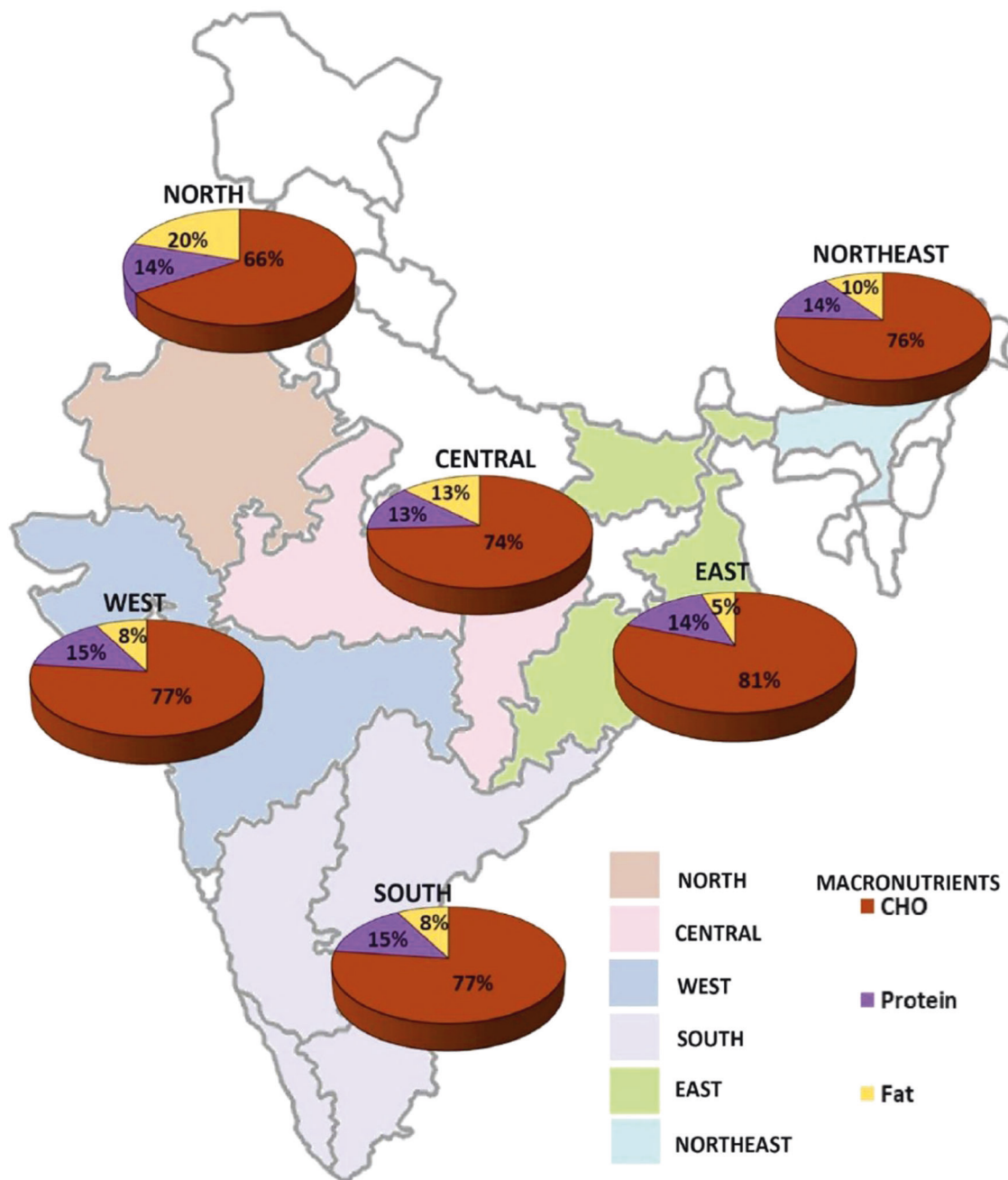


**Fig. 3 Region-wise macronutrient intake in rural Indian adults.** Data from 10 states across four different regions in rural areas were considered as per the National Nutrition Monitoring Bureau rural India survey, 2012. (Source: 'What India Eats' [17]).

physically active lifestyle, which prevented obesity and diabetes from increasing exponentially [53, 54]. A 10-year follow-up study from South India indicated that the risk for diabetes was escalated by 1.85 times with increased intake of refined cereals, 0.66, 0.65 and 0.44 times with decreased FV intake, mono-unsaturated fatty acid (MUFA) and dairy intake, respectively [55]. A multi-center study across the nation showed that dietary patterns such as 'fruit and dairy' and 'snacks and sweets' were positively correlated with abdominal obesity whereas 'pulses and rice' and 'fruit and vegetable' were inversely correlated to diabetes and hypertension, respectively [56]. Consumption of more than 300 g of FV per day is associated with lower odds of developing T2D among Indians [17]. Some of the dietary concerns to be promptly addressed in relation to T2D, obesity and related metabolic diseases in India are as follows.

#### Increased intake of calorie-dense fast foods

Importantly, NSSO data from 1999 to 2012 has shown a persistent increase in per-capita consumption of calorie and fat [50]. Urban Indians are one among the top 10 regular consumers of fast foods in the world. Consumption of take-away foods once or more than once a month was high (about 70%) in urban Indians even during the 2000's [57, 58]. Processed foods such as chips, biscuits, chocolates, sweets and juices constituted 4.1% of energy intake in rural but about three times higher contribution to energy (11.1%) in urban populations [17]. Calorie-dense 'Junk food' consumption has been reported to be very high in rural and peri-urban areas among both children and adults, up to 92.9% [59–61]. In rural populations of South India, as reported by Global Nutrition by International Food Policy Research Institute (IFPRI), the purchase of processed food products of savory alone was found to be 10%



**Fig. 4 Region-wise macronutrient intake in urban Indian adults.** Data from 16 states across six different regions in urban areas were considered as per the National Nutrition Monitoring Bureau urban India survey, 2016. (Source: 'What India Eats' [17]).

between 2000–2014 [62]. Energy contribution from processed foods was found to be more than that of fruits in India [22].

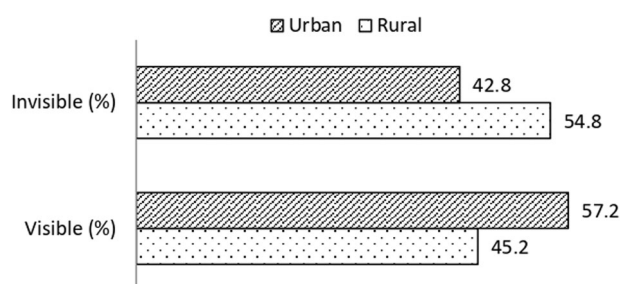
#### Excess intake of simple sugars

India being the largest consumer of sugar, consumed sugar in different forms such as jaggery, *khandasari* (raw, unprocessed sugar crystals) and refined sugar. Indian sweets consumed at different occasions throughout the country are classic examples of energy dense recipes laden with simple carbohydrates, saturated and trans-fats. Additionally, consumption of sugar sweetened beverages (Fig. 6) have exponentially increased over the last two decades [63]. Several reasons such as media advertisements, peer pressure and socio-economic variables may be attributed to the

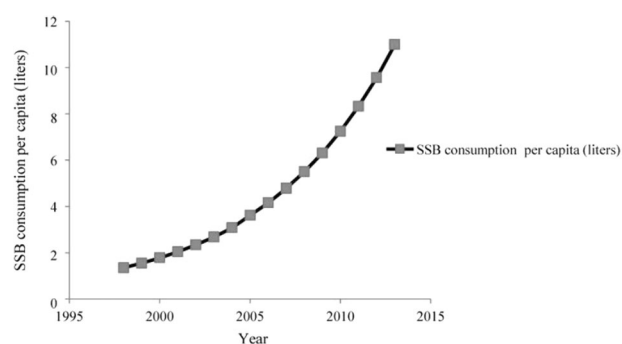
consumption of sugar sweetened beverages [64]. Refined sugar intake is also very high in India. [50].

#### Low intake of dietary fibre

There is enough scientific evidence regarding poor intake of dietary fibre being a risk factor for metabolic disorders and importance of high fibre diets for prevention of diabetes as well [65, 66]. Low consumption of dietary fibre has been reported all over the country in those with and without diabetes. Epidemiological studies have shown the intake of dietary fibre to be 2.87 g/1000 kJ in men and 2.94 g/1000 kJ in women [67]. Recent Indian Council of Medical Research recommendation for dietary fibre is 30 g/2000 Kcal in adults, which can be extrapolated to 18, 22.5 and



**Fig. 5 Visible and invisible fat consumption (in percentage/day) among rural and urban Indian adults.** Visible fat: It consists of oil and fat in fried food and fat derived from meat and poultry; Invisible fat: Fat from Cereal (rice), nuts, pulses, and oilseeds. (Source: 'What India Eats' [17]).



**Fig. 6 Sugar sweetened beverages (SSB) consumption in liters per-capita in India.** SSB include the entire range of carbonated beverages, fruit, energy, and vitamin water drinks containing added sugars. The trend line shows the consumption pattern of SSB between 1998 and 2013 [63].

**Table 3.** Realistic solutions across various domains to mitigate the effect of dietary modifiable risk factor for chronic lifestyle disorders.

Domain	Solutions
(i) At food industry and policy levels	<p><sup>a</sup>Mentioning simple sugars, total visible and invisible fat, saturated fatty acid, trans fatty acid, dietary fibre and sodium content of all packed foods on the food label to be made mandatory.</p> <p><sup>a</sup>Special emphasis on nutritional information of serving size in the food label to be made mandatory.</p> <p><sup>a</sup>Regulation in the use and reuse of oils and the type of oil used in food production, both small and large-scale.</p> <p><sup>b</sup>A colour code for healthy and unhealthy processed foods based on glycemic index, glycemic load, energy density, sodium and total fat content.</p> <p><sup>a</sup>Identifying ways to cut down the high-fat content, sugar and salt in ultra-processed foods added for improved palatability.</p> <p><sup>a</sup>Continuous training and monitoring of food safety and hygiene standards among street vendors and small-scale food outlets.</p> <p><sup>a</sup>Inclusion of millets in Public Distribution System and <sup>b</sup>Mid-day meal programme.</p>
(ii) At clinical and research levels	<p><sup>a</sup>Recording region-wise diet patterns and <sup>b</sup>in-depth analysis of the cultural practices to devise relevant and acceptable measures.</p> <p><sup>a</sup>Determine the influence of local, seasonal and region-specific traditional recipes on the post prandial glycemic response and emphasize on customized preventive and therapeutic nutrition intervention.</p> <p><sup>a</sup>Instead of diets focused on macronutrients, the concept of wholesome meal for lifestyle disorders to be promoted.</p> <p><sup>a</sup>Dieticians and clinicians to employ a more well-rounded approach focusing on physical activity and lifestyle management to minimize disease manifestations.</p>
(iii) At population level	<p><sup>a</sup>Micronutrient intake is compromised when traditional foods and food groups are replaced by high calorie processed foods. Therefore, food diversity (inclusion of various food groups) should be encouraged.</p> <p><sup>a</sup>People should be provided adequate information/ awareness on reading and understanding food labels, which is rudimentary in India compared to the western countries.</p> <p><sup>b</sup>Inculcating awareness among people on serving healthy foods at social gatherings and healthy social eating practices via public platforms/media.</p> <p><sup>a</sup>Consumption of locally grown and seasonal food products to be promoted. Kitchen gardens and consuming fresh foods should be encouraged.</p> <p><sup>a</sup>Strengthen the activities of NetProFaN (Network of Professionals of Food and Nutrition) Pan India and penetrate both the urban and rural masses with the objectives of Eat Right Movement.</p> <p><sup>a</sup>Celebrity endorsements of ultra-processed, non-nutritive, unhealthy and energy dense packaged foods to be discouraged.</p> <p><sup>a</sup>Promotion of healthy lifestyle in schools, colleges and workplaces to prevent lifestyle disorders.</p>
(iv) At individual level	<p><sup>a</sup>Change in knowledge, attitude and practice with regards to self-responsibility in food choices, adverse effect of unhealthy foods and increased physical activity on health.</p> <p><sup>b</sup>Cultivating healthy and responsible social eating practices coping peer pressure and stigmas.</p> <p><sup>a</sup>Taking personal responsibility for quality and quantity of food eaten and making informed choices</p> <p><sup>a</sup>Active participation in community level nutrition programmes conducted by government or institutions.</p>

<sup>a</sup>Initiated.

<sup>b</sup>Proposed.



27 g for the common 1200, 1500 and 1800 Kcal diets, respectively [68]. However, studies have indicated intake of <10 g of crude fibre/day across various regions of India indicating significant inadequacy of total dietary fibre consumption [65].

### Choice of dietary fat

Type of fat (healthy vs. unhealthy fat) consumed is equally significant in its association with health outcomes in addition to the quantity of fat. The observed consumption pattern of high polyunsaturated fatty acids (PUFA) and low MUFA in India is potentially linked to inflammation and metabolic syndrome [69]. A study in South India revealed that the prevalence of metabolic syndrome was higher among people consuming sunflower oil followed by palmolein and traditional oils such as groundnut, gingelly and coconut oils [70]. Dietary profile of South Indians showed that all 6907 adults who participated in the study did not meet the n-3 (PUFA) recommendations [71].

It can be postulated that varying and often unhealthy dietary pattern across regions may be linked to increasing incidence and prevalence of T2D within India; however, there is paucity of research. Region-specific strategies are required to tackle the nutritional shortfalls as a one fit-all programme might not suit the diversified Indian population. High taxation imposed by the government on unhealthy foods, according to simulation studies, could be a feasible solution towards reducing the prevalent high consumption rates. The preventive effect of taxation could be superior to that of traditional consumer and nutrition education programmes on the risk of chronic diseases [72, 73].

### PRIMORDIAL PREVENTION STRATEGIES

Lifestyle modifications have resulted in 28.5% relative risk reduction in incidence of T2D among those with impaired glucose tolerance [74]. Currently, lifestyle modification is perceived in the purview of aesthetics among the public in India; the idea of approaching a qualified dietician or health care professional as a primordial measure in disease prevention is yet to be recognized by a major fraction of the society. Modifying the dietary factors by reducing refined carbohydrates, sugar and high-fat foods in children as well as adults is pivotal in bringing down the incidence and disease burden of T2D [75]. The Food Safety and Standards Authority of India (FSSAI) has recently launched the 'Eat Right Movement' in 2018, a multi-pronged approach to address the food safety and nutrition issues, which needs penetration at various stages to yield results. Eat Right India movement activities are planned along the Indian National Health Policy, 2017 programmes (*Ayushman Bharat*, *Poshan Abhiyaan*, *Anemia Mukta Bharat* and *Swachh Bharat Mission*) with its emphasis on preventive and promotive healthcare [76].

The Eat Right movement with its key themes 'Eat Safe', 'Eat Healthy' and 'Eat Sustainable' has laid emphasis on important aspects related to regulations for food industries, laboratories and food business operators. An important agenda of the movement is 'Social and Behavioral change' by inculcating awareness on appropriate food choices specifically in schools and in general populations. The movement has garnered global attention [77]. Role of taxation on foods High in Fat, Salt and Sugar (HFSS) could be important for mitigating the risk of chronic disorders. Lack of culture-specific approach towards identification of modifiable risk factors, such as socio-economic background, level of literacy, cultural practices and preferences as well as providing culturally acceptable solutions is a major hurdle in the conduction of health behavior changing initiatives. Standard interventions followed for T2D and other lifestyle disorders should be modified and tailor-made risk factors like phenotype, indicators for risk stratification, complications, treatment, dietary habits, occupation and sedentary levels are characteristic to each community or ethno-specific groups [1, 78, 79].

### SOLUTIONS AND NOVEL APPROACHES (SOCIAL AND BEHAVIORAL) TOWARDS PREVENTION AND MANAGEMENT OF T2D IN INDIAN POPULATION

Some of the other approaches that can help mitigate the effect of this epidemic are provided in Table 3. Training stakeholders and mass educational programmes considering the heterogeneity in diet patterns, should be implemented within the existing structure of the far-fetched, exhaustive public healthcare system in India.

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### AUTHOR CONTRIBUTIONS

BM: Designed the work that led to the submission, acquired articles for review and played an important role in interpreting the articles. MA: Conceived, revised the manuscript and approved the final version.

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### ADDITIONAL INFORMATION

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