Original Article

Dietary Fatty-acid Profile of South Indian Adults and Its Association with Type 2 Diabetes—CURES 151

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Abstract

Background: Both the quantity and the quality of fat are major determinants of chronic diseases risk. This paper looks at the fatty-acid composition of Indian foods reported in the diets of urban Asian Indians and its association with type 2 diabetes. **Materials and Methods:** Adults aged 20–80 years (n = 1688) were selected from the Chennai Urban Epidemiological Study. The dietary intake of the study subjects was assessed using a validated food frequency questionnaire. The fatty-acid profile of common foods reported by the population was measured from pooled food samples and substituted in nutrient database for calculation of daily foods, nutrient, and fatty-acid intake. Statistical analysis was performed using Statistical Package for the Social Sciences software. **Results:** Of the foods tested potato chips and Indian sweet *mysorepak* had the highest amount of fat 46.7 g and 42.2 g/100 g, respectively, whereas the Indian sweet *sweet pongal* had the lowest fat of 3.9 g/100 g. Palmitic acid in saturated fatty acid (SFA), oleic acid in monounsaturated fatty acid (MUFA), and linoleic among poly unsaturated fatty acids (PUFA) were commonly reported fatty acids in most foods. Dietary fats provided almost 1/4th of the daily caloric intake of the subjects. Compared to national recommendations, the intake of MUFA and α linolenic acid was very low. Higher intake (>median) of calories (%E) from SFA (P = 0.007) and PUFA (P = 0.008) were associated with an increased risk of type 2 diabetes, whereas MUFA (P = 0.017) showed an inverse association. **Conclusion:** Improvement of the dietary fat profile in our population can be achieved by formulating and propagating guidelines on the selection and appropriate use of cooking oils, and increased consumption of nuts and oilseeds.

Keywords: Fats, fatty acids, mono unsaturated fatty acid, poly unsaturated fatty acids, saturated fatty acid, south Indians, type 2 diabetes

Introduction

Dietary fats play a major role in the etiology of chronic noncommunicable diseases (NCDs) such as obesity, cardiovascular disease (CVD), insulin resistance, and type 2 diabetes (T2D).[1,2,3] Fatty acids (FAs) influence glucose metabolism by altering cell membrane function, enzyme activity, and insulin signaling and gene expression.[4] Both the quantity and quality of dietary fats is important in determining an individual's risk of chronic NCDs. Therefore, it is as important to ensure optimal quality of fat in the diet as it is to limit the consumption of total fat as per recommended dietary allowance (RDA) (20%–30% of total energy intake).[5] There are little data on the dietary fat and FA content and composition of Asian Indian diets, and such information which is particularly important in view of the predilection of Asian Indians to T2D and premature CVD.[6]

In the past, diets were much lower in saturated fatty acids (SFAs) and trans-fatty acids (TFAs) than they are today, with a roughly 1:1 ratio between the amounts of $n6$ and $n3$ polyunsaturated fatty acids (PUFAs).[7] However, in

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recent decades there has been a major shift in the FA intake pattern of the population, probably because of globalization, import liberalization, and urbanization.[8] The debate continues last several decades with regard to dietary fats and health.[9] Recent meta-analysis of randomized controlled trial reported improved glycemia, insulin resistance, and insulin secretion with PUFA as compared to carbohydrate, SFA, or MUFA.[10] However, inconsistent findings are reported about SFA, PUFA, MUFA with CVD and related disease risk.[11] Reports of an expert consultation, Geneva[12] pose a challenge for definitive guidelines about fat. Studies on dietary fats and diabetes risk in Asian Indian adults are sparse.

Although all fats contribute similar amount of calories, their quality in terms of metabolic health varies with the type of FA in the food. It is therefore important to estimate the FA content of the commonly consumed Asian Indian foods to further study the dietary FA profile of a population to assess the detrimental outcomes of dietary fat on the health of the population. This study aimed to assess the dietary FA intake of a south Indian population and its association with the risk of T2D.

Materials and Methods

Subjects

A detailed dietary assessment was performed among adults (≥20 years of age) participating in the urban component of Chennai Urban Rural Epidemiological study (CURES). CURES was conducted on a representative population of Chennai (formerly Madras) city in southern India, with a population of about 6 million people. The methodology of the study has been published elsewhere[13] and is available at https://mdrf.in/misc/CURES.pdf . Briefly, in Phase 1 of CURES, individuals selected by systematic random sampling (n = 26001) were screened for diabetes using fasting capillary blood glucose. In Phase 2 of CURES, 1529 individuals from Phase 1 who had T2D were assessed for prevalence of micro- and macro-vascular complications of diabetes. In Phase 3 of CURES, every 10th individual from Phase 1 (n = 2600) was invited for detailed dietary assessments and from this phase, data of 2032 individuals were available for analysis (response rate 78%). After excluding participants with KD (n = 273) and those reporting implausible energy intake (<500 and >4200 kcal/day; n = 71), 1688 individuals (1491with normal glucose tolerance [NGT] and 197 with newly detected T2D) were included in this study.

Dietary assessment

Dietary intakes were assessed by estimating the usual food intake over the past year using an interviewer-administered, meal-based semi-quantitative food frequency questionnaire (FFQ) containing 222 food items. Interviews were conducted by well-trained nutritionists and participants reported their usual frequency (number of times per day/week/month/year or never) and serving size of the food items listed. A detailed description of this semi-quantitative FFQ and the data on reproducibility and validity has been published elsewhere.[14] Average daily nutrient intake for each listed food item was computed using an in-house database *EpiNu*.

Anthropometry and biochemical assessment

Anthropometric measurements including height, weight, and waist measurements and blood pressure were assessed by trained research assistants using standardized techniques.[13] Biochemical assessment including fasting plasma glucose (glucose oxidase–peroxidase method), serum cholesterol (cholesterol oxidase–peroxidase–amidopyrine method), serum triglycerides (glycerol phosphate oxidase– amidopyrine method), and high-density lipoprotein cholesterol (HDL) (direct method–polyethylene glycol-pretreated enzymes) were measured using a Hitachi 912 Auto analyzer (Roche Diagnostics, Mannheim, Germany). Serum insulin concentration was measured by enzyme-linked immunoassay (Dako, Glostrup, Denmark). Homoeostasis model assessment (HOMA-IR) was used to calculate insulin resistance.[15]

Estimation of fatty-acid content of foods

We prepared a list of 140 frequently (daily/weekly) consumed food items reported in FFQ by the study population, of which 41 cooked/processed foods containing higher amount of fats, such as foods of animal origin, bakery items, deep fried foods, and some Indian sweets for which the FA profile data were not available. Representative food samples of the same type were collected from both commercial (fast food outlets, restaurants, and hotels) and noncommercial (households across diverse socioeconomic groups) establishments across Chennai city. An equal amount of food samples from these different sources were weighed, mixed, and homogenized to obtain a pooled sample, which was then analyzed for FA profile using gas chromatography and as per Indian Standard methods (IS: 548 [Part III-1976]) in a NABL accredited Laboratory.[16]

Statistical analysis

Data analyses were performed using Statistical Package for the Social Sciences software, version 18.0 (SPSS, Chicago, IL). Descriptive statistics such as median and interquartile range (IQR) were used as the data were not normally distributed. Mann–Whitney U test, chi-squared, and k-independent t-test were used to test differences across the groups wherever appropriate. The odds ratio (OR) and 95% confidence intervals (CI) for risk of T2D were determined using less than median intake of each FAs as the reference group, after adjusting for potential dietary and non-dietary confounders. A value of P <0.05 was considered statistically significant.

Results

We estimated the FA content of the commonly reported foods. The FA composition of these foods was updated in the EpiNu in-house database to further assess the dietary FA profile of 1688 urban south Indian adults from CURES study, in relation to risk of T2D.

Table 1 shows the FA composition of 40 foods containing fats that were frequently consumed by the study population. These foods were categorized meal wise into breakfast/dinner (similar choices), lunch (including vegetarian/animal foods), and snacks (deep fried and bakery items). Of all the foods tested, potato chips (snacks) and mysorepak (sweets) had the highest amount of fat (46.7 g; 42.2 g/100 g, respectively), SFA, and PUFA. Lauric acid, oleic acid, and linoleic acid were the major contributors to the SFA, MUFA, and PUFA, respectively, in potato chips. Oleic acid was the predominant MUFA identified in the foods and higher levels of this FA was found in chips, *Jangiri*, *burfi*, and *poori.* Pongal (Sweets) was found to have the lowest amount of total fat (3.9 g/100 g) and SFA (1.7 g/100 g) followed by Chicken biryani (lunch) and dosa (breakfast/dinner). Among the breakfast/dinner food choices poori (21.2 g/100 g) was noted having highest amount of total fat, whereas among lunch and accompaniments beef gravy was found to have the highest amount of total fat (25.6 g/100 g). The TFA content was found only in certain foods mainly selected breakfast / dinner choices, snacks, including sweet preparations and bakery items and ranged from 0.14 to 3.17 g/100 g. The TFA content of vegetable puff (3.17 g/100 g) was the highest, whereas that of pongal (0.14 g/100 g) (breakfast/dinner choice) was the least.

The clinical and biochemical characteristics of the participants are shown in Table 2. Analysis was carried out to identify differences among participants with NGT and newly diagnosed diabetes (NDD). Majority of participants in both NGT (58%) and NDD (62%) groups were females and the age (median) of the participants were 36 and 47 years respectively. Majority of participants in both the NGT and NDD groups followed a sedentary lifestyle and this was high in NDD group (87.8%) The use of sunflower oil was significantly higher among participants in the NDD group (73.6%).

Table 3 shows the average dietary intakes of energy (kcal/d), macronutrients [g/day (%E)], and various food groups (g/day) among the study participants. Carbohydrates formed the bulk of the macronutrient consumption (64.5%) in NGT subjects, followed by fat (25%) and protein (11%). There was no major difference between two groups with respect to the intake of calorie and macronutrients. The intake of sugar and dairy products was reported to be significantly lower in the NDD group, whereas the intake of cereals whole (like wheat flour) and millets was higher compared to NGT groups.

The dietary FA profile of the food consumed by the study population is presented in Table 4. SFAs (8.7% of total calories) were the primary contributor to total fat calories in NGT and significantly higher (P = 0.01) than NDD group (8.1%.). Both MUFA and PUFA contributed to 6%–7% of total calories in both NGT and NDD groups. Linoleic acid was the primary n–6 PUFA consumed and α-linolenic acid was the main contributor to n–3 PUFA intake. The n–3PUFA contributed 0.2% of total calories). Palmitic acid was the main contributor to SFA intake, whereas oleic acid was the main contributor to MUFA intake.

Among the foods groups, edible fats and oils contributed to half of the total fat (52%), more than 80% of PUFA, and 44% of total MUFA intake. Milk and milk products was the main source of SFA (42% of SFA), the second main source for MUFA (22.6% of MUFA) and total fat (21% of total fat)intake in this population. Nuts and oilseeds provided one-fourth of SFA and 12% of total fat and 14% of MUFA intake. About 8% of MUFA, 6% SFA, 5% fat, and 2% PUFA was derived from animal foods. Cereal grains contributed to 6% total fat, 5.4% SFA, 6% MUFA, and around 5% PUFA of the daily dietary intake [Figure 1].

Table 5 compares the total fat and FA intake of study subjects with the recommendations given by the Indian Council of Medical Research.[5] Majority of the study population reported total fat calories were within the recommended levels of 15–30%E. Majority of participants reported consumption of SFA to be less than the recommendation, whereas intake of total PUFA was within recommended energy contribution. However, almost all of the participants did not meet the recommendation for the percentage contribution of energy from MUFA (15–20%E) and n–3 FAs (0.5–2%E).

Further analysis was carried out to study the association between fat and individual FA and the risk of diabetes, individuals consuming lower than median values of respective fat and FAs were considered as reference. Total SFA intake increased the risk of T2D (OR: 2.0; 95% CI = 1.2–3.3, P = 0.007). The risk for T2D was also higher for PUFA (OR, 1.7, 95% CI = 1.2–2.5, P = 0.008). However, MUFA significantly decreased the risk of diabetes risk by almost half (OR 0.54, 95CI = 0.33–0.89, P = 0.017). Potential non dietary and dietary confounders were adjusted in the model [Figure 2].

Discussion

The study is the first of its kind to assess the dietary FA profile of urban adults from south India and its association with the risk of T2D. The key findings of the study indicated greater risk of T2D with increase in SFA (%E) and PUFA (%E), whereas intake of MUFA (%E) reduced the diabetes risk among Chennai urban

Table 1: Fatty-acid composition of foods (g/100 g)

Breakfast/dinner choices	C8:0	C10:0	C12:0	C13:0	C14:0	C16:0	C18:0	C20:0	C22:0	C24:0	C16:1	C18:1t	C18:1C	C18:2c	C18:3	SFA	MUFA	PUFA	TFA	Total fat
Dosa						0.68	0.20	0.03	0.12	0.19	0.08		1.85	0.99	0.07	1.2	1.9	1.1	0.00	4.2
Pongal		0.09		0.10	0.16	1.40	0.50			1.92	0.81	0.16	0.84		0.40	4.2	1.8	0.4	0.14	6.4
Poori					0.17	5.51	0.84		0.17	0.24	0.11		8.34	5.64	0.18	6.9	8.4	5.8	0.00	21.2
Paratha			0.03		0.10	3.20	0.43			0.12	0.06	0.69	3.15	0.68	0.06	3.9	3.9	0.7	0.62	8.5
Noodles - veg			0.07		0.29	1.95					0.06		1.91	0.70	–	2.3	2.0	0.7	0.00	4.5
Lunch, non-vegetarian dishes															–					
Vegetable kurma		0.07	1.03		0.58	2.87	0.45				0.06		3.04	1.12	–	5.0	3.1	1.1	0.00	9.2
Vadai curry			0.16		0.16	2.28	0.43						3.41	2.44	–	3.0	3.4	2.4	0.00	8.9
Curry - spicy gravy			0.51		0.20	0.81	0.40			0.18	0.07		2.79	3.16	–	2.1	2.9	3.2	0.00	8.1
Legumes - gravy	0.06	0.05	0.50		0.24	1.13	0.33						1.76	0.43	–	2.2	1.8	0.4	0.00	4.5
Pickle						2.03	1.01				0.78			3.42	–	3.0	0.8	3.4	0.00	7.2
Biriyani-veg				0.02	0.02	1.00	0.25			0.82	0.13		1.36	1.23	0.03	2.1	1.5	1.3	0.00	4.9
Briyani – chicken					0.06	0.76	0.27			0.10	0.13		1.44	1.40	–	1.2	1.6	1.4	0.00	4.2
Briyani – mutton			0.05		0.08	1.40	0.35				0.04	0.18	1.83	1.51	0.04	1.9	2.1	1.6	0.16	5.5
Gravy – chicken		0.15	1.58		0.79	2.79	0.55				0.11		3.64	3.07	–	5.9	3.7	3.1	0.00	12.7
Gravy mutton			0.45		0.44	2.24	1.38				0.36		3.63	2.48	–	4.5	4.0	2.5	0.00	11.0
Fry – chicken					0.15	3.85	0.90	0.09			0.45		7.50	8.25	0.06	5.0	8.0	8.3	0.00	21.2
Fry – mutton			0.12		0.28	3.76	1.06	0.05			0.11		6.37	5.46	0.04	5.3	6.5	5.5	0.00	17.3
Fish - gravy / curry			0.31		0.24	1.61	0.68				0.89		1.80	0.48	–	2.8	2.7	0.5	0.00	6.0
Fish - fry					0.20	4.75	1.36				1.19		5.98	3.52	–	6.3	7.2	3.5	0.00	17.0
Prawn, Crab - curry			0.15	0.11	0.12	1.98	0.90				0.97		3.84	2.33	–	3.3	4.8	2.3	0.00	10.4
Prawn, Crab - fry						4.29	2.06				0.45		3.19	1.03	0.09	6.3	3.6	1.1	0.00	11.1
Pork / beef - gravy			1.34		1.21	7.58	2.48				1.28		9.81	1.86	–	12.6	11.1	1.9	0.00	25.6
Snacks															–					
Medu vada					0.10	4.13	0.68		0.15	0.19	0.15		6.00	3.33	0.16	5.3	6.1	3.5	0.00	14.9
Samosa /cutlet					0.17	5.91	0.82						7.45	2.78	–	6.9	7.4	2.8	0.00	17.1
Potato chips	0.96	1.08	9.52		4.28	8.98	1.72						12.03	9.07	–	25.6	12.0	9.1	0.00	46.7
Bakery products																				
Bun					0.07	2.50	0.29				0.03	0.48	1.96	0.70	0.04	2.9	2.5	0.8	0.45	6.1
Biscuits -plain					0.14	4.94	0.76	0.05		0.14	0.08		4.35	1.50	0.04	6.0	4.4	1.5	0.00	12.0
Biscuits - sweet			0.27		0.27	7.04	1.37			0.22	0.04		5.74	1.90	0.14	9.2	5.8	2.0	0.00	17.0
Biscuits - salt		0.42	5.28		1.71	7.37	1.00	0.07		0.26			7.21	2.21	0.06	16.1	7.2	2.3	0.00	25.6
Cake-plain, sponge					0.20	7.55	1.24			0.28	0.27	1.02	6.63	1.77	–	9.3	7.9	1.8	0.92	19.0
Cake-cream			0.16		0.20	6.50	0.97	0.04		0.13	0.21	0.63	6.39	1.74	0.06	8.0	7.2	1.8	0.58	17.0
Puff -veg			0.46		0.41	8.95	1.01	0.04		0.31	0.10	3.51	5.20	1.19	0.07	11.2	8.8	1.3	3.17	21.2
Sweet preparations															–					
Pongal		0.04	0.07		0.26	1.32					0.06	0.49	1.47	0.22	–	1.7	2.0	0.2	0.44	3.9
Kesari / sheera					0.28	3.67	0.73				0.10	0.98	2.84	0.42	–	4.7	3.9	0.4	0.88	9.0

Table 1: Continued

Breakfast/dinner choices	C8:0	C10:0	C12:0	C13:0	C14:0	C16:0	C18:0	C20:0	C22:0	C24:0	C16:1	C18:1t	C18:1C	C18:2c	C18:3	SFA	MUFA	PUFA	TFA	Total fat
Ladoo / jilebi		0.12	0.20		0.92	6.02	1.53		0.21	0.28	0.27		7.33	3.84	0.21	9.3	7.6	4.0	0.00	20.9
Jangiri					0.48	7.34	1.35		0.37	0.41	0.22		11.46	6.21	0.30	10.0	11.7	6.5	0.00	28.2
Mysore pak/mohan dhal			0.73		3.39	11.52	4.20				1.93	0.78	11.27	7.91	–	20.3	14.0	7.9	0.70	42.2
Milk sweets			1.74		1.61	5.43	2.05				0.43	0.50	3.88	0.49	0.13	11.2	4.9	0.6	0.45	16.7
Burfi			1.18		0.74	3.76	1.54		0.65				9.29	7.48	0.40	7.9	9.3	7.9	0.00	25.0
Confectionery																				
Chocolate commercial			1.90		1.04	7.03	1.69					5.06	6.91	0.95	0.30	11.7	12.0	1.3	0.00	24.9

C8:0 = caprylic, C10:0 = Capryic, C12:0 = lauric, C13:0 = trideconic, C14:0 = myristic, C16:0 = palmitic, C18:0 = stearic acid, C20:0 = arachidic, C22:0 = behenic, C24:0 = lignoceric, C16:1 = palmetoleic, C18:1c = oleic, C18:2t = linoelaidic, C18:2c = linoleic, C18:3 = linolenic

adults despite majority of them reported well within the national recommendations for dietary SFA and PUFA and almost all of the participants below the recommendation for MUFA. Among the commonly reported fats containing foods by the Chennai urban adults, snacks such as potato chips and Indian sweet *mysorepak* showed the highest fat content than meal choices and animal foods.

Fatty-acid composition of foods

Indian food composition tables[17] provide data only for the raw and uncooked food ingredients. Although there are few studies on the FA profile of few of the Indian foods,[18-20] there is no comprehensive database on the same despite the critical need. This study has assessed the FA composition of the commonly consumed home cooked and processed foods by chemical analyses, a better method than using computed values based on raw and uncooked FA values. The FA profile of foods depends solely on the type of edible fat/oil used for its preparation, as different edible fats have different profile of FAs[21,22] Thus, high levels of palmitic acid present in chips, bakery products (including vegetable puff), and some sweets might be because of the use of palm oil for their preparation. Khan *et al.*[20] studied the FA profile of different varieties of commercial Indian biscuits, cookies, and cream biscuits, and reported wide variations depending on the type of the product. The fat content ranged from as low as 9.5% fat in plain biscuit to about 25% fat in cashew cookies and almost all the biscuits contained TFA, ranging from as low as 0.7 (in glucose biscuits) to 17% in butter biscuit. The fat content observed for plain and sweet biscuits in this study corroborated with the results discussed above.

The highest amount of TFA was found in vegetable puff contributing about 3.17 g/100 g and this corroborates with the results of Khan *et al.*,[20] who had earlier shown 2.6% TFA for Indian pastry. the total fat content in vegetable puff almost matched with their results (21% total fat in our study as against 20% in their study). Similarly, Reshma *et al.*[23] also reported the trans-fat content of vegetable puff to be highest (3.09 ± 1.5%) among the bakery products including fried foods tested.

Total fat

The Joint FAO/WHO Expert Consultation[12] suggests that the total fat contributes between 20% and 30% of daily calories, whereas the position statement from Academy of Nutrition and Dietetics on dietary FAs for human health recommended 20% to 35% of daily calories from fat.[24] In this study, dietary fats comprised about 25% of the daily caloric intake of urban south Indian adults from Chennai. This is similar to the intakes reported elsewhere in India.[25,26]Though the dietary fat intake is within the RDA in this population, data from national surveys suggest that the total fat intake (in g/day) of the population has

Table 2: Clinical characteristics of the study population (*n* = 1688)

Description	NGT (n = 1481)		Newly diagnosed DM (n = 197)		*P* value
	Median	IQR	Median	IQR	
Age (years)	36.0	17.0	47.0	19.0	0.001
Sex					
Male	42.0		37.6		0.236
Female	58.0		62.4		
Body mass index (kg/m^2)	22.8	6.4	25.8	5.7	0.001
Waist circumference (cm)	82.7	17.5	89.5	14.4	0.001
Systolic blood pressure (mm Hg)	113.0	22.0	127.0	26.5	0.001
Diastolic blood pressure (mm Hg)	71.0	15.0	80.0	16.0	0.001
Fasting glucose (mg/dL)	84.0	10.5	132.0	60.5	0.001
Fasting insulin (µmol/mL)	6.0	5.7	11.0	9.0	0.001
Total cholesterol (mg/dL)	173.0	48.0	196.0	41.5	0.001
Triglyceride (mg/dL)	95.0	65.0	147.0	106.0	0.001
High density lipoprotein (mg/dL)	42.0	14.0	41.0	11.0	0.001
Low-density lipoprotein (mg/dL)	107.0	41.0	124.0	37.8	0.001
HOMA IR	1.3	1.3	3.6	2.6	0.001
Income (rupees)					
<2000	36.5		37.4		
2000–5000	48.7		47.3		0.988
5000–10000	12.0		12.1		
>10000	2.8		3.3		
Physical activity (%)					
Sedentary	76.7		87.8		
Moderate	20.7		12.2		0.001
Vigorous	2.6		0.0		
Cooking oil (%)					
Traditional oils[a]	10.0		6.1		
Palm oil	23.3		20.3		0.095
Sunflower oil	66.7		73.6		
Qualifications (%)					
Illiterate	13.0		20.8		
Below SSC	48.7		47.9		
Only SSC	25.2		24.0		0.177
Graduate	11.2		6.3		
Postgraduate	1.9		1.0		

NGT, normal glucose tolerance, NDD = newly diagnosed diabetes, IQR = inter quartile range

[a]Groundnut and gingelly oil

increased dramatically over the last few decades (1993–94 vs. 2011–12) in both rural (31.4–41.6 g/day) as well as urban (42–52.5 g/day) India.[27] Rapid urbanization and socioeconomic growth could be one of the reasons for increase in dietary fat intake in India, where diets have traditionally been low in fat, especially saturated fat. Increased availability of fats and oils at affordable prices could also have contributed to increased intake of dietary fat in India. Data from FAO[28] and other studies[29,30] show that there has been an increase in the %E obtained from fats (14 to19%) and vegetable oils (6 to 10%) in India from 1980 to 2000In this study, visible fat (cooking fats and oils) was found to account for half of the total fat intake, as compared to one-third, as shown in earlier studies.[31] Bradley[32] in a recent review of observational, biomarker, and clinical research reported that total dietary fat consumption is not associated with risk for T2D. This is consistent with the findings of this study. Furthermore, the studies also suggest that the composition of fat rather than total dietary fat may play a role in diabetes risk.[33,34]

Saturated fatty acids

SFAs accounted for about 8.5% of daily caloric intake, among urban adults in Chennai which is higher than the recommend intake of <7% to prevent obesity, MS, and DM.[35] Palmitic acid was the predominantly consumed SFA followed by stearic, lauric, and myristic acids. Palmitic (44%), stearic (20%), and myristic (16%) acids also represent the bulk of total SFA in milk fat.[36] In this study, milk and its products were the primary source of SFAs, followed by edible fats and oils. We found palm oil to be the second most commonly used cooking oil probably because of its

Table 3: Mean intake of nutrients and food groups by the study population (n = 1688)

Variables	NGT (n = 1481)		Newly diagnosed DM (n =197)		*P* value
	Median	IQR	Median	IQR	
Energy kcal/day	2538	897	2608	1354	0.469
Carbohydrate g/day	412.1	143.8	410.6	249.5	0.505
Carbohydrate %Es	64.5	7.9	65.5	6	0.326
Protein g/day	70.6	26.1	72.4	37.6	0.686
Protein %E	11.2	1.4	11.2	1.7	0.788
Dietary fiber g/2000 kcal	23.9	6.5	23.9	6.8	0.974
Cereals, refined g/day	330.9	164.9	338.6	265.9	0.356
Cereal, whole and millets g/day	11.1	15.2	13.1	14.3	0.022
Pulses legumes g/day	48.6	24.7	49.7	22.8	0.321
Dairy products g/day[a]	357	316.9	307	268.9	0.003
Fruits & vegetable g/day[b]	321.7	186.8	312.9	199.5	0.185
Meat & poultry g/day	16.3	21	15.9	24.1	0.917
Fishes and sea foods g/day	16.9	16.9	16.1	13	0.098
Eggs g/day	16.6	16.6	15	21	0.936
Edible fats and oil g/day	31.8	16.1	32.6	20	0.882
Nuts and oilseeds g/day	18.2	12.4	18.2	12.3	0.681
Sugar	16.5	18.4	11.7	21	0.001

NGT, normal glucose tolerance, NDD = newly diagnosed diabetes, IQR = inter quartile range

[a]Dairy products include milk, yoghurt, cheese, and buttermilk

[b]Fruits and vegetables include fruits, leafy vegetables, other vegetables, and roots

Table 4: Fatty-acid profile of foods consumed by the study population (n = 1688)

Descriptive	NGT (n = 1481)		Newly diagnosed DM (n = 197)		*P* value
	Median	IQR	Median	IQR	
Fat g/day	64.8	29.8	64.7	39.2	0.94
Fat %E	23.5	5.9	23.0	5.8	0.29
SFA	24.0	12.2	23.3	15.7	0.22
SFA (%E)	8.7	3.0	8.1	2.8	0.01
Lauric acid (12:0)	2.4	1.5	2.2	1.5	0.05
Myristic acid (14:0)	2.3	1.3	2.0	1.4	0.005
Palmitic acid (16:0)	12.5	6.9	12.0	8.6	0.45
Stearic acid (18:0)	4.2	2.2	4.0	2.7	0.19
Atherogenic acid (lauric, myristic, palmitic)	17.4	9.4	16.8	12.2	0.29
MUFA	19.2	9.2	18.9	11.5	0.71
MUFA (%E)	6.9	2.1	6.8	1.8	0.29
Palmitoleic acid (16:1)	0.7	0.5	0.6	0.5	0.07
Oleic acid (18:1)	17.9	8.4	17.6	10.7	0.76
PUFA	17.3	11.6	18.0	11.9	0.14
PUFA(%E)	6.2	3.8	6.5	3.3	0.09
Total n–3 (ALA,EPA,DHA,DPA)	0.6	0.3	0.6	0.4	0.09
Total n–3 (%E)	0.22	0.08	0.2	0.07	0.01
Linoleic acid (18:2)	16.8	11.6	17.4	11.9	0.13
Alpha linolenic acid (18:3)	0.59	0.31	0.57	0.33	0.13
EPA (20:5)	0.01	0.02	0.01	0.01	0.01
DPA (22:5)	0.01	0.01	0.01	0.01	0.43
DHA (22:6)	0.02	0.02	0.02	0.02	0.12
n6/n3 ratio	28.1	18.8	30.7	18.1	0.09
Trans fatty acid	0.12	0.19	0.12	0.23	0.34
Trans fatty acid (%E)	0.00	0.10	0.00	0.10	0.08

NGT, normal glucose tolerance, NDD = newly diagnosed diabetes, IQR = inter quartile range

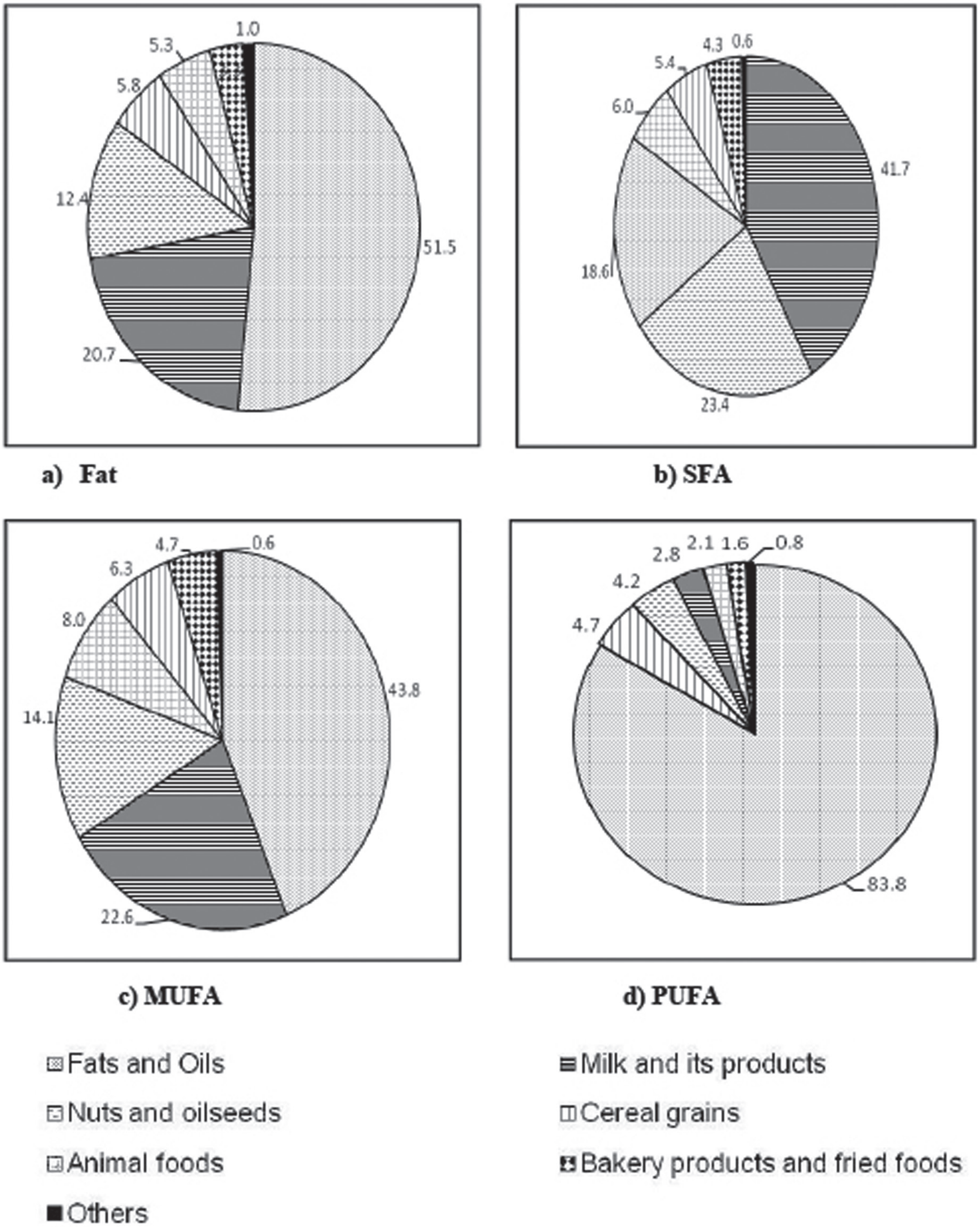

Figure 1: Sources of food groups (%) contributing to the intake of fat and fatty acid among Chennai urban adults (*n* = 1688)

cheaper cost and availability in public distribution systems (PDS). The role of SFA in relation to health outcomes, especially risk of T2D, is controversial.[37] Report from National Health Survey suggests that higher intake of SFA significantly increased the risk of T2D by about 34%. On the contrary, several studies have shown consumption of SFAs from regular/low fat dairy products to be protective against diabetes risk.[38,39,40] Furthermore, FAO stated that SFAs might be associated with insulin resistance and T2D.[28] The PREDIMED study also reported a greater risk of T2D with intake of SFA.[41] We also report an increased risk of T2D with greater than median intake of SFA even at 8.6%E after adjusting for potential confounders. Thus, it is important to limit the intake of SFA especially among Asian Indians who are already at risk of premature heart disease and T2D.

Table 5: Percentage distribution of the study population by their adequacy in the intake of total fat and fatty acids as compared to recommended levels (*n* = 1688)

Description	Recommended Intake (%E)[a]	No. of subjects consuming			*P* value
		Less than recommended intake *n* (%)	Meeting the recommended intake *n* (%)	Greater than recommended intake *n* (%)	
Total fat	15–30	38 (2.2)	1542 (91.3)	108 (6.4)	<0.001
SFA	<10	–	1236 (73.2)	452 (26.8)	<0.001
MUFA	15–20	1688 (100)	–	–	–
PUFA	6–10	742 (44.0)	842 (49.9)	103 (6.1)	<0.001
LA (n6)	2.5–9	104 (6.2)	1403 (83.1)	181 (10.7)	<0.001
ALA (n3)	>0.5	1687 (99.9)	1 (0.1)	–	<0.001

[a]Joint FAO/WHO Expert Consultation[12]. Fats and fatty acids in human nutrition. Report of an expert consultation, November 10–14, 2008, Geneva

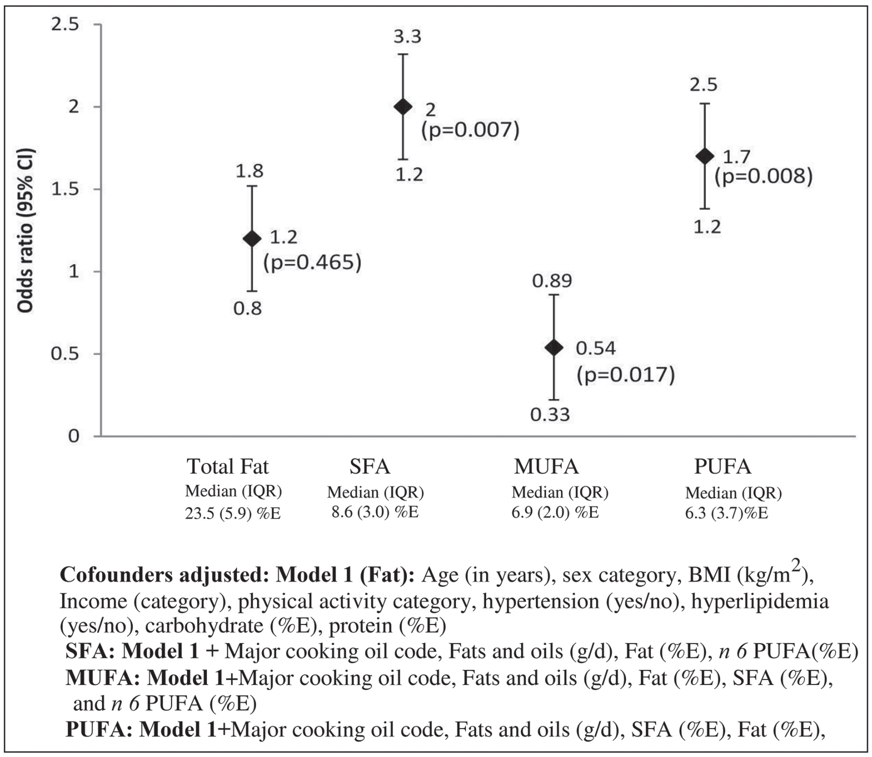

Figure 2: Association of fatty acids with the risk of type 2 diabetes in urban adult population of Chennai

Polyunsaturated fatty acids

Linoleic acid (*n*–6 PUFA) and α linolenic acid (*n*–3 PUFA) are the main dietary PUFAs, which have structural and functional roles in all cells. Diet with a high ratio of *n*–6: *n*–3 PUFAs showed a trend toward decreasing insulin sensitivity.[42,43] One study has shown that *n*–6 PUFAs in the diet are an independent predictor of fasting hyperinsulinemia in Asian Indians.[44] Oils such as sunflower, safflower, corn, soybean, sesame, and rice bran oil as well as cereals (except ragi [finger millet]) and pulses (except black gram) are rich sources of *n*–6 PUFAs.[45] A recent study from our group has also shown that use of sunflower oil which is rich in *n*–6 PUFAs and commonly used among South Indians for cooking was associated with higher risk of metabolic syndrome as compared to other traditional oils such as groundnut, gingelly, and mustard oil.[43] Studies among the present population as well as among Israeli population have also shown increased risk of CVD, diabetes, and hypertension associated with higher consumption of n–6 PUFA.[46,47] In this study, intake of PUFA greater than even 6% E doubled the risk of diabetes as compared to less than median intake (<6%E)

n-3 PUFA tends to lower total cholesterol and fasting and postprandial triglycerides and increase the HDL cholesterol.[48-50] Several studies suggest that a balanced intake of *n*–6 and *n*–3 FAs can reduce the risk of many chronic conditions including diabetes, CVD, and obesity.[51] Bradley[32] reported that consumption of fish and marine *n*–3 FAs was associated with reduced diabetes risk among the Asian population. The Singapore Chinese health study also showed that *n*–3 FA was inversely associated with incidence of diabetes among Chinese men and women.[52] Recent recommendations suggest increasing consumption of *n*–3 PUFAs (e.g., two or more servings of fatty fish per week to provide at least 500 mg eicosapentaenoic and docosahexenoic acid per day) so that at least 0.5% to 2% energy is obtained from *n*–3 FAs and 5% to 10% energy from *n*–6 FAs per day.[5] However, the intake of *n*–3 PUFA-rich foods like fish is low in our population (20 g/day).[53]

Indian diets could possibly be modified using oils with moderate or low levels of linoleic acid such as groundnut, rice bran, and gingelly oil as well as blended oils and consuming foods rich in α linolenic acid such as mustard and soya bean oil, pulses, fenugreek, nuts, green leafy vegetables, and fish.[31,54] It is well established that linoleic acid can be converted to arachidonic acid in the body which has pro-inflammatory effects leading to increased risk of metabolic syndrome.[41]

Monounsaturated fatty acids

Oleic acid was the MUFA most commonly consumed by the study population. Evidence suggests that substitution of calories from carbohydrate or SFA with MUFA may lower CVD risk.[55,56] Anjana *et al.*[46] reported low intake of MUFA as one of the contributing factors associated with greater increase in incidence of T2D in South India. Likewise, switching from PUFA to MUFA (linoleic acid to oleic acid) was found to be beneficial in reducing insulin resistance in men.[57,58] Paniagua *et al.*[59] also showed that MUFA rich diet improved insulin resistance as well as fasting pro insulin levels compared to isocaloric carbohydrate and SFA rich diet among participants with insulin resistance. Recently a met analysis showed that olive oil rich in MUFA may perhaps be beneficial in prevention and management of T2D.[60] Similarly, a study among Asian Indians showed that use of olive oil elicited a significant decrease in body mass index, insulin resistance and fasting blood glucose compared to safflower oil and canola oil.[61] In this study, MUFA intake of >7%E decreased the risk of T2D by almost 50%. However, none of the study participants met FAO/WHO (2008) MUFA %E recommendations of 15–20%E. One reason for such low intake of MUFA could be the replacement of traditional MUFA-rich cooking oils, such as groundnut oil, with oils such as soybean oil and sunflower oil. This is also evident from our previous studies on the same population, in which the most commonly consumed oils were found to be sunflower oil (64%) and palm oil (21%), and groundnut oil (8%).[53,43] Nuts are another rich source of MUFA, recently a randomized controlled trial with cashew nut (30 g/day for 3 months) among adults with T2D resulted in an increase in HDL cholesterol and a decrease in blood pressure and almonds (contributing 20% of the total energy intake) showed improvement in the lipid profile and reduction in glycosylated hemoglobin, thereby showing its beneficial effects on glycemic and CVDs risk factors in Asian Indian patients with T2D.[48] Thus, the findings of MUFA consumption having a protective effect on T2D are of immense interest.

Our study has several strengths; this is the first study to profile FAs in commonly consumed foods in southern India by analytical methods and provides evidence that SFA and PUFA in this population are risk factors for T2D diabetes. One of the limitations is although our study has suggested a link between FA profile and diabetes, no cause–effect relationship could be established as ours is a cross-sectional study. Dietary data collected by validated FFQ and the nutrient data were also based on the main cooking oil reported by the study population to get the best precise FA intake, another important strength to this study. Detailed dietary studies and intervention trials are required to corroborate these data and to evaluate the effects of individual fats and FAs on health.

Conclusion

In summary, our study shows that although intake of total and saturated fat intake in this population is within the recommended limits, the quality of fat is suboptimal, as exemplified by low intake of MUFA which confer protective health effects at 7%E level, whereas higher intake of SFA and PUFA even at the levels of 8.6%E and 6%E, respectively, and within the recommended intake increases the risk of diabetes. Improvement of the dietary fat profile in our population can be achieved by formulating and propagating evidence based guidelines on the selection and appropriate use of cooking oils, and increased consumption of nuts and oilseeds in addition to fish wherever possible.

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Conflicts of interest

There are no conflicts of interest.

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