Original Article

# Prospective Associations between a Food-Based Indian Diet Quality Score and Type 2 Diabetes Risk among South Indian Adults (CURES-154)

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## Abstract

**Background:** Asian Indians are culturally different and have diverse dietary and culinary habits. Further, there are potential biological differences in metabolism due to genetic or cultural factors. This warrants the development of a unique population-specific food-based diet score for prevention of noncommunicable disorders. **Materials and Methods:** Dietary intake was assessed using a validated food frequency questionnaire in 1033 adults who participated in the 10-year follow-up study of Chennai Urban Rural Epidemiological Study (CURES). The diet score was developed considering eight food groups and one major cooking oil that were either significantly associated with a higher or lower risk of incident type 2 diabetes (T2D). The foods that showed a protective effect was assigned higher scores and vice versa for foods that increased the risk of diabetes assigned the lower. We further assessed the effect of Indian Diet Quality score (IDQS) and three popular diet quality indices: the Healthy Eating Index-2015 (HEI), the Dietary Approach to Stop Hypertension (DASH), and Diabetes Diet Score (DDS) in relation to the risk of incidence of diabetes among Indian population. **Results:** Higher IDQS is associated with a significant lower risk of diabetes incidence; however, no such significant association was observed with diet quality indices (DASH, HEI-2015, and DDS) and diabetes incidence. This warrants the need for population-specific diet score for Indians. **Conclusion:** Higher IDQS was associated with a lower risk of T2D among South Indian adults. Thus, IDQS can be a suitable tool to identify the diet–disease relationship especially in a population with diverse dietary intakes.

**Keywords:** Diet score, incidence of diabetes, South Indian adults

## Introduction

Prevalence of type 2 diabetes (T2D) has steadily risen across the globe with most of the increase occurring in developing countries (India and China in particular). The recent Indian Council of Medical Research–India Diabetes (ICMR-INDIAB) study reported that the prevalence of diabetes and prediabetes in India currently stands at 7.4% and 10.3%, respectively.[1] According to the latest International Diabetes Federation figures, India currently has 88.0 million people with T2D and this is projected to increase to 153 million by the year 2045.[2] Substantial evidence shows that diabetes can

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be prevented or delayed through a healthy diet, regular physical activity, and maintaining normal body weight.[3]

Diet is a major determinant of health and a primary modifiable risk factor for noncommunicable diseases (NCDs) including T2D.[4] It has been estimated that adopting a healthy diet reduces the risk of diabetes by 30% in the South Asian population.[3] Several different dietary patterns and indices including the Dietary Approach to Stop Hypertension (DASH),[5,6] Healthy Eating Index (HEI) or Alternative Healthy Eating Index (AHEI),[7,8] and Mediterranean diet[9] have been widely identified and tested in Western populations for the prevention and management of NCDs. However, Asian Indians being culturally different have diverse dietary and culinary habits and potential biological differences were observed in metabolism due to genetic or cultural factors. Hence, diets prescribed as healthy in the West may not be appropriate for Asian Indians who are considered to be at increased risk for T2D and cardiovascular disease (CVD).

Many risk scores predict the development of diabetes with a fair degree of accuracy. However, till date there is no perfect risk score that is applicable globally, as several factors including the context of use, local/regional characteristics of, and traditions need to be considered. Earlier studies from Asian Indians have shown independent association of several dietary factors with T2D and CVD.[3,10-15] Recently, the urban component of Chennai Urban Rural Epidemiology Study (CURES) identified an unhealthy diet score derived from both foods and nutrients as a modifiable risk factor for diabetes incidence.[3] The Mediators of Atherosclerosis in South Asians Living in America study identified the metabolic risk among South Indian adults living in the United States using the dietary pattern approach.[16] However, till date very limited studies have identified the combined effect of the various food groups concerning diabetes risk among Asian Indian population. Thus, in this study, we aimed to develop a healthy dietary score for Indians, called the Indian Diet Quality score (IDQS). In addition, the study aimed to assess the independent association of IDQS with incidence of diabetes among Asian Indian adults.

## Materials and Methods

### Study population

The baseline CURES was conducted between the year 2001–2003 and included 26,000 adults from 46 corporation wards of Chennai city in Tamil Nadu state of southern India using a systematic sampling technique (Phase I).[17] This study population included 1382 individuals with self-reported diabetes ($n$ = 1382), who were assessed for diabetes complications in Phase II. In Phase III, every 10th participant from Phase I was randomly chosen for detailed demographical, clinical, biochemical, and dietary assessments ($n$ = 2207). The follow-up cohort consisted of these 2207 individuals plus the 1382 found to have self-reported diabetes in Phase I ($n$ = 3589).

The follow-up survey was conducted between 2012 and 2013. During the 10-year follow-up, 534 individuals died and 645 were lost to follow-up; thus, a total of 2410 individuals completed the cohort study. Dietary data were available for 1981 individuals. After excluding individuals with known diabetes ($n$ = 799), known hypertension and CVD ($n$ = 90) and baseline implausible energy intakes (<500 kcal and >3500 kcal) for female (<800 kcal and >4000 kcal) for male ($n$ = 59), this study included 1033 adults.

The study was carried out following the Declaration of Helsinki and Good Clinical Practice Guidelines (World Medical Association, International Conference on Harmonization). Ethical Approval was obtained from the Institutional Ethics Committee and written informed consent was obtained from all the study participants. Death ascertainment was obtained from participants' family and the causes of death were determined from the medical records or death certificates and a verbal autopsy was obtained by trained physicians wherever applicable.

### Data collection

Demographical (including medical history and physical activity), anthropometric, biochemical, and dietary data were collected both at baseline (2001–2003) and after 10 years (2012–2013) using a structured, protested, and validated interviewer-administered questionnaire. Family history of diabetes was considered as positive if either parents or siblings had diabetes. Smokers were defined as those who were currently smoking, and alcohol use was defined as current alcohol consumption.

Height, weight, waist circumference (WC), and blood pressure were measured using standardized techniques,[17] and body mass index (BMI) was calculated as weight in kilograms divided by height in $m^2$. Biochemical analyses, including fasting plasma glucose and lipids, were performed in all individuals; also, plasma glucose estimation 2 h after a 75 g oral glucose load was performed in individuals without diabetes.[17] Biochemical analyses were performed in a laboratory certified by the National Accreditation Board for Testing and Calibration Laboratories and the College of American Pathologists on a Hitachi 912 Auto analyzer (Hitachi, Mannheim, Germany) using kits supplied by Roche Diagnostics (Basel, Switzerland) for estimation of plasma glucose (glucose oxidase-peroxidase [GOD-POD] method).

### Outcome ascertainment

Diabetes was diagnosed at follow-up by an oral glucose tolerance test performed in all participants. A venous blood sample was drawn for estimation of plasma glucose levels in the fasting state and 2 h following oral administration of 75 g of glucose dissolved in 300 mL water. Individuals with either fasting plasma glucose levels ≥ 126 mg/dL or 2-h plasma glucose ≥ 200 mg/dL were categorized as diabetes. In the case of self-reported (known) diabetes, onset status was validated with medical records.[18]

### Dietary assessment

Dietary intake was assessed by trained dietitians using a validated open-ended semi-quantitative 222-item food frequency questionnaire (FFQ) both at baseline and follow-up. The development and validation of the same have been described elsewhere.[19] The FFQ included both the frequency and the servings of food items consumed by the individuals that were then converted to standardized portion sizes. However, any new food item reported (new market foods over a 10-year period) during the follow-up period was updated in the in-house software "EpiNu."

### Development of Indian Diet Quality score

The participants' reported dietary intake of various foods in grams per day was calculated using the in-house software EpiNu (Chennai, Tamilnadu, India). All the food groups were energy-adjusted by the residual method.[20] The reference cutoff value of the food group that positively or negatively associated with the risk of diabetes was identified with the multivariate model (hazard ratio [HR]) by stratifying the food intake into several equal groups (quantile).

The food groups in the IDQS were given weightage based on their association with risk for diabetes. The highest quintile of those foods that elicited protective effect (decreased risk of diabetes) was given a score of "10," whereas the lowest quintile of food groups was scored "0." The scoring was vice versa for foods that showed a negative effect. For instance, the highest quintile of, for example, white rice intake was given a score of "0," whereas the lowest quintile was scored "10." For the intake of <53.6 g/d (min) of protective food such as pulses and legumes a least score of "0" was assigned, whereas for intake >64.3 (max) a highest score of 10 was given. However, for intake between the minimum and maximum intakes, a proportionate score was derived using the following formula.

For example, if an individual's reported daily intake of pulses and legumes was 60 g/day, then

$$IDQS = 10 - \left( \frac{10 * \ (reported\ intake\ of\ protein - max)}{[Min - max]} \right)$$

$$= 10 - \left( \frac{10 * \ (60 - 64.3)}{[53.6 - 64.3]} \right) = \ 6.0$$

The vice versa was used for foods that were significantly positively associated with the risk for diabetes such as white rice. In addition to food groups, the main type of cooking oil reported was also considered for scoring. This was based on our previous study in this population,[15] wherein the use of sunflower oil was associated with a higher risk of insulin resistance and metabolic syndrome compared to traditional (gingelly and groundnut oil) oils and palmolein oil. Hence, those individuals using traditional oils were given a score of "10," whereas the use of sunflower oil was scored "0" and use of palmolein was given a mid-score of "5."

Each individual was given a separate score for eight food groups (*pulses and legumes, milk and its products, fruits and vegetables*, *white rice, edible fats and oils, added sugar, added salt, and poultry and egg*) and one type of cooking oil and the score was summed to determine the total IDQS for each individual. The score ranged from minimum "0" to a maximum score of "90." Similarly each individual's DASH,[6] HEI,[21] and diabetes diet score (DDS)[22] was determined based on the respective scoring systems described.

## Statistical Analyses

Statistical analyses were performed using SAS software program, version 9.0 (SAS Institute Inc., Cary, NC). All food groups and nutrients were energy-adjusted by the residual method. We used analysis of variance to investigate the association of 30 food groups with the incidence of diabetes in a multivariate model adjusted the confounders (confounders are listed in Table 1). Of these food groups, only eight food groups and one cooking oil were significantly associated either negatively or positively with diabetes and were included in the IDQS development. The IDQS scores were then divided into quartiles for further analysis. As nutrients and food groups were not normally distributed, estimates were expressed in median and IQR and the differences were tested using Wilcoxon sign-rank test. Quartiles of IDQS, HEI, DASH, and DDS were assigned for each individual from reported dietary intake at baseline. The HR for the incidence of diabetes in each quantile of various food groups was calculated using Cox proportional hazards analysis after adjusting for age, sex, and other potential confounders as listed in Tables 1 and 2. The linear trend across the quantile food groups and diabetes incidence were tested with regression model.[23] General linear models were used to test the construct validity and to obtain age, sex, and physical activity levels (PALs) adjusted mean BMI and WC across quartiles. Difference between the quartiles was assessed using Kruskual–Wallis test for all the continuous variables. The *P* values were tested for statistical significance at <0.05 level.

## Results

This study included 1033 adults from the CURES, who completed both baseline and 10-year follow-up assessments. The baseline characteristics of the study

**Table 1: Construction of Indian Diet Quality score: Food groups and its association with incidence of type 2 diabetes among Chennai adults from Chennai Urban Rural Epidemiological Study ($n$ = 1033)**

| Food groups | Classification | Quintiles[¥] | Median (95%CI) | Serving size (medium size) | Tools | HR (95% CI) | Score ^ | $P$ for trend |
|---|---|---|---|---|---|---|---|---|
| Pulses and legumes (g) | Lowest | Q1–Q3 | 43.3 (40.4–42.3) | 0.3 | m.cup | 1 | 0 | 0.001 |
| | Medium | Q4 | 58.2 (58.0–58.8) | 0.4 | m.cup | 0.62 (0.41–0.93) * | 0–10^ | |
| | Highest | Q5 | 73.2 (75.3–79.1) | 0.5 | m.cup | 0.50 (0.32–0.78) * | 10 | |
| Milk and its products (g) | Lowest | Q1 | 164.9 (129.5–153.8) | 1.2 | m.glass | 1 | 0 | 0.001 |
| | Medium | Q2–Q4 | 368.3 (375.5–390.1) | 2.6 | m.glass | 0.74 (0.48–0.98) * | 0–10^ | |
| | Highest | Q5 | 743.3 (764.9–814.9) | 5.3 | m.glass | 0.42 (0.22–0.81) * | 10 | |
| Fruits and vegetables (g) | Lowest | Q1 | 218.2(199.9–212.4) | 2 | m.cup—any fruits and veg., | 1.00 | 0 | 0.035 |
| | Medium | Q2–Q4 | 350.1 (346.8–354.9) | 4 | m.cup—any fruits and veg., | 0.60 (0.60–0.89) * | 0–10^ | |
| | Highest | Q5 | 545.7 (563.2–596.3) | 5 | m.cup—any fruits and veg., | 0.56 (0.33–0.95) * | 10 | |
| White rice (g) | Lowest | Q1 | 235.4(230.9–239.8) | 1.6 | m.cup—cooked white rice | 1 | 10 | 0.028 |
| | Medium | Q2–Q4 | 374.0 (367.2–373.2) | 2.6 | m.cup—cooked white rice | 1.84 (1.17–2.88) * | 0–10^ | |
| | Highest | Q5 | 444.2 (462.4–482.1) | 3.1 | m.cup–cooked white rice | 2.42 (1.22–4.80) * | 0 | |
| Edible fats and oils (g) | Lowest | Q1 | 25.1 (23.3–24.3) | 5 | tsp—cooking oils | 1 | 10 | 0.001 |
| | Medium | Q2–Q4 | 33.3(32.9–33.3) | 7 | tsp—cooking oils | 1.68 (1.11–2.55) * | 0–10^ | |
| | Highest | Q5 | 41.4 (42.6–44) | 8 | tsp—cooking oils | 2.33 (1.43–3.80) * | 0 | |
| Added sugar (E %) | Lowest | Q1 | 0.6 (0.4–0.6) | – | – | 1 | 10 | 0.007 |
| | Medium | Q2–Q3 | 2.4 (2.3–2.5) | – | – | 1.57 (0.95–2.52) | 0–10^ | |
| | Highest | Q4–Q5 | 5.2 (5.7–6.2) | – | – | 1.99 (1.21–3.28) * | 0 | |
| Added salt (g) | Lowest | Q1 | 5.0 (4.5–4.9) | 1.0 | tsp | 1 | 10 | 0.003 |
| | Medium | Q2–Q4 | 7.6 (7.5–7.6) | 1.5 | tsp | 2.32 (1.15–4.68) * | 0–10^ | |
| | Highest | Q5–Q10 | 10.3 (10.8–11.2) | 2.1 | tsp | 2.98 (1.47–6.01) * | 0 | |
| Poultry and egg (g) | Lowest | Q1–Q4 | 11.0 (9.7–10.9) | 0.2 | m.cup /m.no | 1 | 10 | 0.019 |
| | Medium | Q5–Q9 | 32.1 (32.3–33.8) | 0.7 | m.cup /m.no | 1.28 (0.98–1.83) | 0–10^ | |
| | Highest | Q10 | 68.2 (72.3–92.5) | 1.5 | m.cup /m.no | 1.69 (1.05–3.22) * | 0 | |
| Major type of cooking oil[£] | Traditional oils[α] | 10 | | | | | | |
| | Palmolein oil | 5 | | | | | | |
| | Sunflower oil | 0 | | | | | | |

CI = confidence interval, HR = hazard ratio

*Fruits and vegetable:* Whole fruits (excluded juice), other vegetables, roots, and green leafy vegetables (removed tubers). Milk and its products include milk, coffee, tea, cheese, and curd and butter milk. Multivariate model adjusted for age (years), sex (male and female), body mass index (kg/m$^2$), waist circumference (cm), smoking (yes/no), alcohol (yes/no), physical activity (PAL), income (Rs. <2000, 2000–5000, 5000–10,000, >10,000), systolic and diastolic blood pressure (mm Hg), and energy (kcal). In addition, the food groups were adjusted mutually for each other's

^Calculated proportionally

£The scoring for major cooking oil was given based on our previous study findings by Lakshmipriya *et al*.[15]

¥Refers to the quintile or centiles of particular food groups that significantly increased or decreased risk for diabetes. Serving size: Dr. Mohan's Atlas of Indian foods.[35]

m.cup = 150 mL, m.glass = 140 mL, and tsp = 5 m

*$p < 0.05$ significant

**Table 2: Hazard ratio of incidence of diabetes according to the Indian Diet Quality score, Dietary Approaches to Stop Hypertension, Healthy Eating Index 2015, and diabetes diet score ($n$ = 1033)**

| | Q1 ($n$ = 258) | Q2 ($n$ = 258) | Q3 ($n$ = 258) | Q4 ($n$ = 259) | *P* for trend |
|---|---|---|---|---|---|
| | Reference | HR (95% CI) | HR (95% CI) | HR (95% CI) | |
| IDQS | | | | | |
| Crude HR | 1.00 | 1 (0.69–1.46) | 0.87 (0.59–1.28) | 0.87 (0.6–1.28) | 0.3763 |
| Age and sex adjusted | **1.00** | **0.87 (0.60–1.23)** | **0.78 (0.53–1.16)** | **0.41 (0.27–0.64)**** | **<0.001** |
| Multivariate model | **1.00** | **0.83 (0.56–1.22)** | **0.71 (0.47–1.06)** | **0.41 (0.27–0.64)**** | **<0.001** |
| DASH[6] | | | | | |
| Crude HR | 1.00 | 1.13 (0.76–1.70) | 1.11 (0.74–1.65) | 1.28 (0.86–1.89) | 0.255 |
| Age and sex adjusted | 1.00 | **0.60 (0.34–0.95)**** | 0.85 (0.57–1.29) | 0.93 (0.62–1.40) | 0.701 |
| Multivariate model | 1.00 | 0.61 (0.39–0.96)** | 0.91 (0.59–1.39) | 0.86 (0.57–1.29) | 0.995 |
| HEI-2015[21] | | | | | |
| Crude HR | 1.00 | 1.06 (0.74–1.54) | 0.86 (0.58–1.28) | 0.93 (0.62–1.37) | 0.744 |
| Age and sex adjusted | 1.00 | 1.11 (0.76–1.60) | 0.56 (0.35–0.88) | 1.07 (0.72–1.59) | 0.957 |
| Multivariate model | 1.00 | 1.01 (0.68–1.51) | 0.60 (0.37–0.97) | 1.09 (0.70–1.70) | 0.748 |
| DDS[22] | | | | | |
| Crude HR | 1.00 | 1.05 (0.71–1.56) | 1.16 (0.8–1.68) | 1.01 (0.68–1.49) | 0.8250 |
| Age and sex adjusted | 1.00 | 1.45 (0.92–2.26) | 1.67 (1.09–2.55) | 1.38 (0.89–2.14) | 0.1471 |
| Multivariate model | 1.00 | 1.34 (0.85–2.11) | 1.59 (1.03–2.46) | 1.22 (0.78–1.90) | 0.3740 |

HR = hazard ratio, CI = confidence interval, IDQS = Indian Diet Quality score, DASH = Dietary Approaches to Stop Hypertension, HEI-2015 = Healthy Eating Index 2015, DDS = diabetes diet score

Multivariate model adjusted for age, sex, smoking, alcohol, physical activity, household income, body mass index (>22.9 kg/m$^2$) > 22.9 kg/m$^2$, systolic and diastolic blood pressure, and energy in quartiles

**$p < 0.001$ significant

**Table 3: Baseline characteristic of the study population ($n$ = 1033)**

| Description | Overall ($n$ = 1033) | Male ($n$ = 433) | Female ($n$ = 600) | Male vs. female |
|---|---|---|---|---|
| | Median (IQR)/$n$ (%) | Median (IQR)/$n$ (%) | Median (IQR)/$n$ (%) | *P* value* |
| Age (years) | 36 (15) | 37 (14) | 36 (15) | 0.509 |
| Gender $n$ (%) | – | 433 (41.9) | 600 (58.1) | – |
| Smoking (yes) $n$ (%) | 160 (15.5) | 159 (36.7) | 0 (0) | <.0001 |
| Alcohol (yes) $n$ (%) | 242 (23.4) | 242 (55.9) | 0 (0) | <0.001 |
| Income per month $n$ (%) | | | | |
| Rs. <2000 | 297 (29.4) | 103 (24.4) | 194 (32.9) | 0.008 |
| Rs.2000–5000 | 516 (51.0) | 220 (52.1) | 296 (50.2) | |
| Rs.5000–10000 | 162 (16.0) | 82 (19.4) | 80 (13.6) | |
| Rs. >10000 | 37 (3.7) | 17 (4.0) | 20 (3.4) | |
| Family history of diabetes (yes) $n$ (%) | 449 (43.5) | 181 (41.8) | 268 (44.7) | 0.359 |
| Waist circumference (cm) | 84 (16) | 86 (17) | 82 (17) | 0.001 |
| BMI (kg/m$^2$) | 23.2 (6.2) | 22.7 (6) | 23.7 (6.4) | 0.001 |
| Systolic BP (mm Hg) | 113 (20) | 117 (17) | 112 (22) | 0.085 |
| Diastolic BP (mm Hg) | 72 (13) | 72 (12) | 71 (16) | 0.047 |
| Fasting blood glucose (mg/dL) | 84 (12) | 84 (11) | 84 (12) | 0.898 |
| Postprandial blood glucose (mg/dL) | 106 (33) | 102 (33) | 107 (31) | 0.002 |

BMI = body mass index, BP = blood pressure, IQR = interquartile range

**P* value was tested by chi-square test for categorical and Wilcoxon Sign rank test for continuous variable

participants are described in Table 3. The median age was 37 (14) years and 36 (15) for men and women, respectively. Of them, 45% of women and 42% of men reported having a family history of diabetes. A significant difference was observed in the monthly income, BMI (man vs. woman: 22.7 [6.0] vs. 23.7 [6.4] kg/m$^2$), WC (man vs. woman: 86 [17] vs. 82 [17] cm), and postprandial blood glucose (man vs. woman: 102 [33] vs. 107 [31] mg/dL) between men and women.

HRs were determined to see the association of food groups with the incidence of diabetes. The food groups were divided into equal groups and based on their association

**Table 4: Nutrients and food groups according to quartiles of India Diet Quality Score ($n$ = 1033)**

| Description | Q1 ($n$ = 258) | Q2 ($n$ = 258) | Q3 ($n$ = 258) | Q4 ($n$ = 259) | *P* | *r* |
|---|---|---|---|---|---|---|
| Score (mean) | 31.4 (6.8) | 39.9 (3.1) | 47.3 (4.1) | 58 (8.7) | <.0001 | |
| Energy (kcal) | 2657.8 (965.5) | 2351.7 (988) | 2362.2 (830) | 2407.9 (756.6) | <.0001 | –0.14** |
| Carbohydrate (E%) | 65.8 (7.1) | 65.4 (7.6) | 64.5 (7.5) | 63.2 (7.8) | <.0001 | –0.15** |
| Carbohydrate (g) | 441.8 (159.9) | 389.3 (164.7) | 380.9 (120.1) | 377.3 (112.7) | <.0001 | –0.19** |
| Glycemic load | 250.4 (43.6) | 246.3 (49.1) | 240.2 (46.9) | 230.9 (45) | <.0001 | –0.22** |
| Weighted glycemic index | 66.9 (3.4) | 66.5 (4.3) | 65.7 (4.1) | 64.8 (4.4) | <.0001 | –0.29** |
| Dietary fiber (g)/1000 | 9.6 (4.9) | 11.6 (5.1) | 12.3 (5.3) | 12.9 (4.7) | <.0001 | 0.24** |
| Protein (E %) | 11.2 (1.5) | 11.2 (1.7) | 11.2 (1.5) | 11.5 (1.6) | <.0001 | 0.13** |
| Protein (g) | 70.7 (23.2) | 65.1 (24.7) | 66.7 (20.7) | 67.3 (25.9) | <.0001 | –0.07* |
| Fat (E %) | 23.3 (5) | 23.3 (6.7) | 23.7 (6.7) | 24.6 (5.8) | <.0001 | 0.14** |
| Fat (g) | 64.1 (26.9) | 59.4 (27.2) | 61.6 (24.4) | 64.7 (28.9) | 0.009 | –0.01 ns |
| Total SFA (E %) | 7.7 (2.1) | 7.9 (2.8) | 8.2 (2.4) | 8.8 (2.7) | <.0001 | 0.22** |
| Total SFA (g) | 21.1 (10.7) | 19.3 (10.8) | 21.8 (9.6) | 22.7 (11) | <.0001 | 0.06* |
| Total PUFA (E %) | 7.5 (2) | 7.5 (2.6) | 7.5 (2.6) | 7.3 (2.4) | 0.93 | 0.01ns |
| Total PUFA (g) | 21.8 (8.8) | 19.4 (9) | 19.5 (8.4) | 19.6 (9.6) | <.0001 | –0.07* |
| Total MUFA (E %) | 6.5 (1.7) | 6.4 (2) | 6.4 (1.7) | 6.6 (1.8) | 0.62 | 0.02 ns |
| Total MUFA (g) | 18.1 (8.2) | 16.7 (7.6) | 16.7 (6.5) | 17.2 (7.9) | <.0001 | –0.08* |
| PUFA n-6 (E %) | 7.4 (2) | 7.3 (2.6) | 7.2 (2.8) | 7 (2.5) | 0.84 | –0.01 ns |
| PUFA n-6 (g) | 21.3 (9.1) | 18.6 (9) | 19 (8.4) | 18.8 (9.5) | <.0001 | –0.08* |
| PUFA n-3 (E %) | 0.2 (0.1) | 0.3 (0.1) | 0.3 (0.1) | 0.3 (0.1) | <.0001 | 0.34** |
| PUFA n-3 (g) | 0.7 (0.3) | 0.7 (0.3) | 0.7 (0.3) | 0.8 (0.4) | <.0001 | 0.22** |
| PUFA n-6/n-3 | 31.4 (10.5) | 29.4 (8.9) | 27.5 (9.2) | 24.8 (9.9) | <.0001 | –0.31** |
| Calcium (mg) | 835.4 (303.7) | 855.1 (333.7) | 973.2 (347.3) | 1091.4 (417.3) | <.0001 | 0.42** |
| Potassium (mg) | 1076.3 (288.5) | 1162.4 (347.9) | 1253.9 (329) | 1378.6 (376.6) | <.0001 | 0.48** |
| White rice (g) | 329.1 (102.4) | 321.3 (119) | 304.4 (98) | 294.1 (101.5) | <.0001 | –0.22** |
| Wheat whole and refined (g) | 31 (27.5) | 32 (26.2) | 31.6 (29.6) | 28.4 (27.1) | 0.37 | –0.03ns |
| Legumes dhal and whole (g) | 47.2 (14.3) | 50.4 (16.6) | 52 (21.4) | 57.4 (25) | <.0001 | 0.25** |
| Fat and edible oils (g) | 35.5 (9.5) | 33.7 (11.9) | 32.2 (10.9) | 30.4 (10.5) | <.0001 | –0.08* |
| Fruits and vegetable (g) | 307.6 (138.5) | 339.1 (127.4) | 358 (157.6) | 392.7 (187.9) | <.0001 | 0.28** |
| Milk and its products (g) | 290.5 (159) | 330 (193.6) | 404.9 (247.1) | 516.3 (308.8) | <.0001 | 0.43** |
| Animal foods (g) | 64.5 (44.3) | 50.8 (36) | 48.4 (38.9) | 37.8 (32.6) | <.0001 | –0.35** |
| Poultry and egg (g) | 37.2 (25.7) | 25.6 (22.2) | 22.1 (22.6) | 16.6 (16.2) | <.0001 | –0.36** |
| Added salt (g) | 8.8 (3.1) | 8 (3.9) | 8.3 (4.7) | 8.2 (4.6) | 0.01 | –0.06ns |
| Added sugar (g) | 19.8 (17.8) | 16.5 (17.2) | 15.5 (20.4) | 11.3 (14.9) | <.0001 | –0.2** |
| Sugars (E%) | 3.4 (2.4) | 3.1 (3.1) | 3 (3.5) | 2.1 (2.7) | <.0001 | –0.08* |

SFA = saturated fatty acid, PUFA = poly unsaturated fatty acid, MUFA = monounsaturated fatty acid, ns = not significant

*P* value tested by Kruskal–Wallis test. Correlation tested by Spearman correlation coefficient

*$p$<0.05 significant, **$p$<0.001 significant

with T2D the groups were combined for further analysis. For instance in the food group "pulses and legumes" (divided as quintiles Q1–Q5), quintiles Q1–Q3 elicited no significant association; however, a significant decrease was observed in risk of T2D in both Q4 and Q5. Hence for further analysis and scoring, we classified quintiles Q1–Q3 as lowest intake and quintiles Q4 and Q5 that showed a significant reduction in risk of diabetes as medium and highest intakes, respectively [Table 1]. The association of various food groups in association with incidence T2D is given in Table 1. Significant negative associations were observed for incidence of T2D with pulses and legumes (g) (Q1–Q3 vs. Q5 HR [confidence interval, CI]: 0.50[0.32–0.78]; *P* for trend *P* = 0.001), milk and its products (g) (3%–4% milk, Indian yogurt, butter milk, and cheese) (Q1 vs. Q5: 0.42[0.22–0.81]*; *P* for trend *P* = 0.001), and fruit (without juice) and vegetables (except tubers)(g) (Q1 vs. Q5: 0.56[0.33–0.95]*; *P* for trend *P* = 0.035). Positive associations were noted for white rice (g) (Q1 vs. Q5: 2.42[1.22–4.80]*; *P* for trend *P* = 0.028), fats and edible oils (g) (Q1 vs. Q5: 2.33[1.43–3.80]*; *P* for trend *P* = 0.001), added sugar %E (Q1 vs. Q4–Q5: 1.99[1.21–3.28]*; *P* for trend *P* = 0.007), added salt (g) (Q1 vs. Q5–Q10: 2.98[1.47–6.01]*; *P* for trend *P* = 0.003), and poultry and egg (g) (Q1–Q4 vs. Q10: 1.69[1.05–3.22]*; *P* for trend *P* = 0.019).

Table 4 shows the nutrient and food group profile of individuals based on IDQS in quartiles. The individuals in highest quartile of IDQS were found to have lower intake of energy, carbohydrates (g/day and %E), glycemic load, glycemic index, protein (g), poly unsaturated fatty acids (PUFAs) (g) especially linoleic acid, monounsaturated fatty acids (MUFAs) (g), and sodium (mg/day). Intake of dietary fiber g/1000 kcal, protein (%E), total fat (%E), saturated fatty acids (SFAs) (%E), *n*-3 PUFA (g/d), calcium (mg/d), and potassium (mg/d) were significantly higher in the fourth quartile of IDQS as compared to the first quartile. Among food groups, intake of white rice (g/d), edible oils and fats (g/d), animal foods (g/d), poultry and egg (g/d), added sugar (g/d), and sugar (%E) was lower, whereas intake of legumes and dhal (g/d), fruits and vegetables (g/d), and milk and milk products (g/d) was higher in the fourth quartile as compared to the first of IDQS. A similar association was observed by the Spearman correlation of the nutrients and food groups with IDQS.

Figure 1 shows the mean BMI and WC of the study population according to the quartiles of IDQS at both baseline and post-follow-up as a measure of the construct validity. Both BMI and WC were significantly inversely associated with IDQS even after adjusting for age, sex, and PALs suggesting a good measure of construct validity of the IDQS.

Table 2 shows the associations of IDQS, DASH, HEI-2015, and DDS with the incidence of diabetes. A significant inverse association was observed between highest quartile of IDQS and HR for diabetes after adjustment for age and sex (Q1 vs. Q4 HR: 0.41[0.27–0.64, *P* for trend $P < 0.001$]). The results were similar even after further adjustment for other confounders including smoking, alcohol, PAL, household income, BMI (kg/m$^2$), systolic and diastolic blood pressures, and energy intake (in quartiles) (Q1 vs. Q4 HR: 0.41[0.27–0.64], *P* for trend $P < 0.001$). Being in the highest quartile of IDQS reduced the risk for diabetes by almost 60%. In this population, no significant association was observed between the DASH, HEI-2015, and DDS scores and risk of diabetes even after adjustment for potential confounders.

Figure 2 shows the sensitivity analysis of the IDQS with risk for diabetes stratified by age, sex, BMI, and PAL categories. A 1-unit or 5-unit increase in diet score reduced the diabetes risk significantly by 3% and 15%, respectively. The association between diet score and the incidence of diabetes was prominent among both gender (male and female), older adults (>30 years), overweight and obese (BMI >22.9 kg/m$^2$) individuals, and those with higher PALs (>median 1.65).

## Discussion

The findings of this study suggest that individuals with high IDQS elicited a lower risk of diabetes; further, the reduction was more prominent among older, overweight and obese adults as well as individuals with higher PAL. However, in this population diet scores based on the DASH diet, HEI, and DDS had no association with T2D. The study findings may perhaps educate individuals on healthy dietary food choices to reduce the risk of diabetes as diet is one of the key determinants of obesity and diabetes.

There is growing interest in research on the development of diet scores and their relation to chronic disease epidemiology as it takes into consideration the synergistic effect of the overall dietary intake of the population rather than specific single nutrients or food groups. In the West, early studies have assessed the relation between the quality of diet (diet score) and risk of diabetes (DDS). However, in most studies (AHEI and HEI), the diet quality was determined based on previously published scientific evidence or recommended guidelines. These studies include common rating systems and similar food groups, including higher intake of whole grains, fruits and vegetables, nuts and low-intake of red and processed meat, and foods high in sugar and salt; all of which elicit

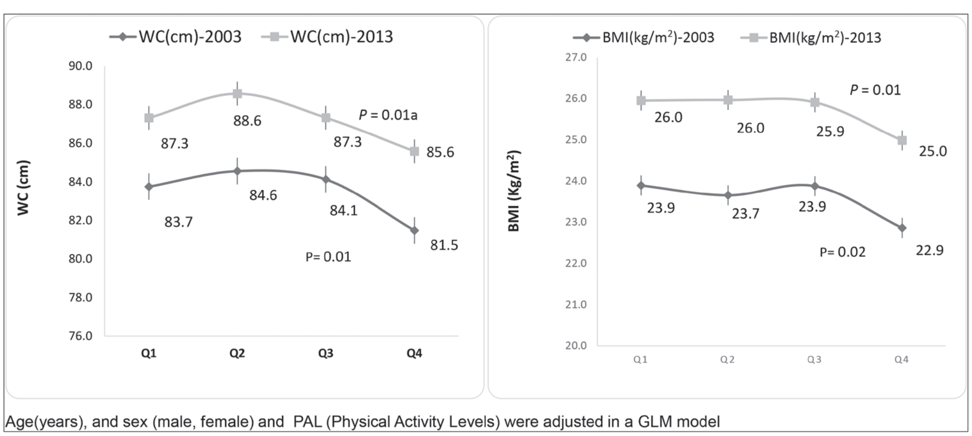


**Figure 1:** Body mass index (BMI) and waist circumference (WC) distribution of study population based on the quartile of diet score ($n$ = 1033). Age (years), sex (male and female), and physical activity levels (PALs) adjusted in a General Linear Model

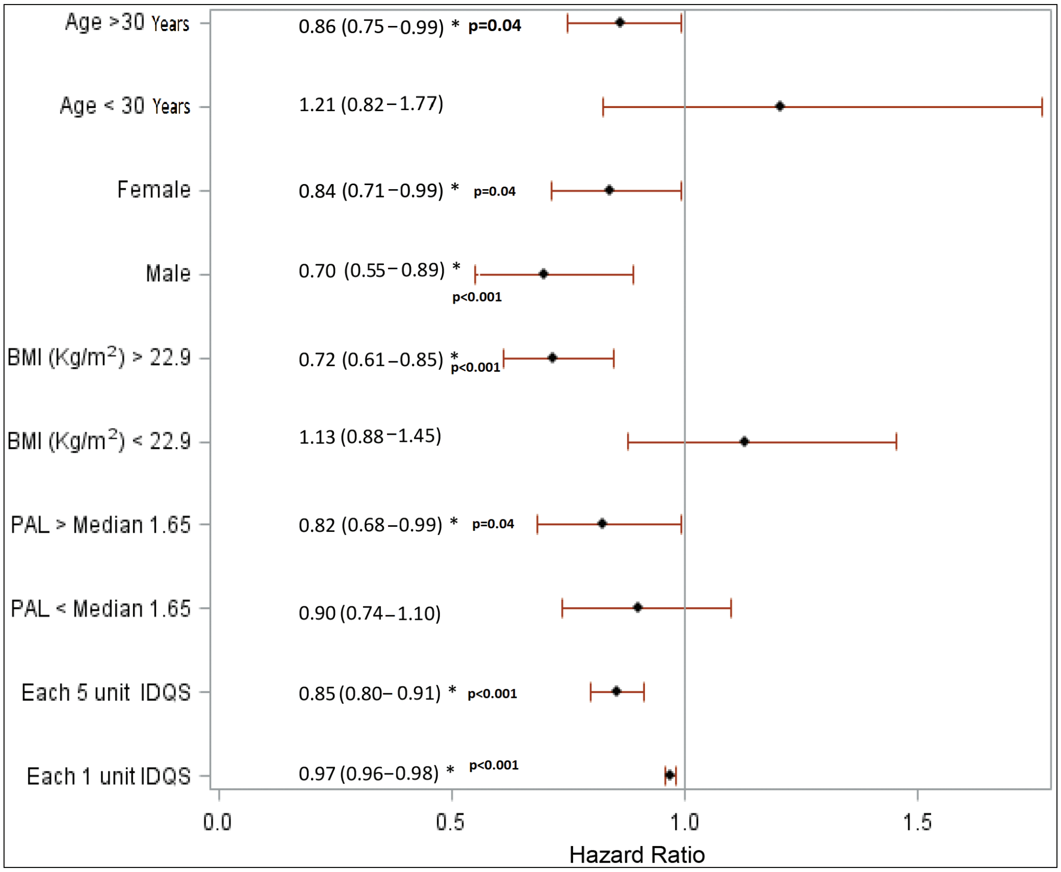


**Figure 2:** Sensitivity analysis of Indian Diet Quality score (IDQS) and its association with incidence of type 2 diabetes stratified by age, sex body mass index (BMI) (kg/m$^2$), and physical activity level (PAL). Multivariate model adjusted for age (years), sex (male and female), smoking (yes/no), alcohol (yes/no), PAL, house hold income (Rs. <2000 , 2000–5000, 5000–10,000, and >10,000), BMI (kg/m$^2$), systolic blood pressure (mm Hg), diastolic blood pressure (mm Hg), and energy intake (kcal/day) in quartiles. *Significant at <0.05 level

protective effect against diabetes risk, thereby suggesting an underlying common dietary practice. Such studies are not suitable for the Asian Indian population due to differences in culinary and dietary habits. For instance, Asian Indian diets are cereal staple-based as compared to Western diets that are high in animal foods and fat. Thus, it is necessary from a public health perspective to develop a country- or region-specific unique diet score in relation to NCDs including T2D as it makes use of the best scientific knowledge available within populations[24-26] and can be updated[27] or modified based on revised dietary guidelines with scientific evidence to prevent chronic diseases.[8,28]

The recommended dietary allowance (RDA) for Indians also suggests food group-based recommendations for healthy adults, and that too based on their physical activity.[29] Further, among the Asian Indian population, there is a lack of evidence-based food group scoring for prevention of NCDs. Satija *et al.*[30] identified three dietary patterns that were associated with general and central obesity among Indians. However, the major limitation of this study was that the three patterns included either one of the foods such as refined grains, sweets, or red meat that are unhealthy. Hence, in this study, the IDQS was derived taking into consideration the dietary habits specific to Asian Indians. Further, in addition to IDQS, we also assessed the association between the modified DASH diet for diabetes,[6] HEI[21] and DDS[22] to assess their applicability in this population.

Although the IDQS shared some food group in common to the DASH, HEI, and DDS, there were differences in each diet score concerning the categorizing and scoring of food groups. For instance, food group such as “low-fat dairy” that was a part of DASH and DDS was not included in the IDQS as “low-fat dairy” is not very commonly reported by this population. Unlike DASH and DDS, the IDQS has given a score for the food group “milk and milk products” (including milk, curd, and buttermilk). Similarly, seafood and meat that was a part of other three diets was not given consideration in this study as the reported consumption was found to be low (meat: 7.3 g/d; fish: 7.9 g/d) and hence could not elicit any association with diabetes risk. Further, pulses and legumes that were protective against diabetes were included in IDQS scoring but in DASH diet legumes were combined with nuts and seeds and grouped as plant proteins in HEI, whereas it was not included in the DDS score as the association between legumes and incident diabetes was not conclusive. Although Western studies have shown the association between sugar-sweetened beverages and diabetes risk (18), it was not included in IDQS as the reported intake in this population was found to be low (8.3 g/d). White rice was one of the components of IDQS as it is the major contributor of refined grains, calorie, and carbohydrates among Asia Indians, whereas the other diets included either total grains or whole grains, which is comparatively low in this population. In addition to the food groups, the type of cooking oil and salt were also included in IDQS. In earlier studies from this population, the components of IDQS have independently shown similar associations with risk of T2D and other cardiometabolic risk factors that predispose to diabetes.[10,12,13,15,31]

Several studies among different population groups have shown a reduction in diabetes risk with different diet scores such as DDS, HEI 2015, DASH diet, and Mediterranean diets. Dominguez *et al.*[22] in a study with DDS from Seguimiento Universidad de Navarra (SUN) cohort among Spanish adults reported a 49% reduction in diabetes incidence. The DDS also elicited a greater reduction in diabetes risk among overweight or obese adults and among older individuals similar to this study. However, this DDS when tested in this study population elicited no significant reduction in diabetes incidence. This is mainly attributed to the differences in food groups between the 2 score. For instance, DDS score included foods such as whole grains, dietary fiber, red meat and nuts, which are not included in the IDQS due to minimal intake reported by the study population. Likewise, the DASH diet score that has earlier shown an inverse association with diabetes among white individuals failed to show similar association in blacks or Hispanics.[6] However, the same DASH score when applied to our study population it was not significantly associated with diabetes risk reduction.

In a study among Chinese adults, diet score based on HEI had no effect on diabetes risk, whereas high diet score based on China Dietary Guideline Index was associated with a low risk.[32] Similarly, a diet score slightly modified based on Australian HEI was inversely associated with diabetes only in men and had no effect among women.[33] Chen *et al.*[34] showed that dietary scores derived from the alternate Mediterranean diet, alternative HEI, the DASH diet, an overall plant-based diet index, and healthful plant-based diet index were associated with a lower risk of diabetes among Asian adults in the Singapore Chinese Health Study.

The study has several strengths; the first being includes a longitudinal design with good sample size. The prospective nature of the study and use of validated FFQ that captures the local dietary habits of the population are added strengths. The scoring thus developed based on food groups and not nutrients could make public health message easily translated as people eat food and not nutrients. The study also has certain limitations. Firstly, the dietary assessment is subject to recall bias. Secondly, although we have adjusted for all those potential confounders, residual confounding is unavoidable in epidemiological studies. Thirdly, a number of individuals were lost to follow-up, and fourthly, this score was developed only based on the population dietary habits. Intakes of several healthy and unhealthy foods such as intact whole grains, nuts, animal foods including processed meats, and sugar-sweetened beverages were low and hence these foods could not be evaluated in this population. Finally, the findings of this study are confined to the South Indian urban population and have to be confirmed in other regions and among rural populations in India.

In conclusion, a healthy diet score thus developed for urban Indian adults was associated with a lower risk of T2D. This simple inexpensive diet score can be used to educate laypeople and to encourage individuals at risk of diabetes to improve their dietary choices. These healthy choices, proved to prevent T2DM, may also influence the incidence of other NCDs; therefore, widespread dissemination of such score is warranted. The challenge is to now scale this up to the population level.

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## Conflicts of interest

There are no conflicts of interest.

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