

Association of fruit and vegetable intake with cardiovascular risk factors in urban south Indians

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The study examines the relationship between fruit and vegetable intake (g/d) and CVD risk factors in urban south Indians. The study population comprised of 983 individuals aged ≥ 20 years selected from the Chennai Urban Rural Epidemiological Study (CURES), a population-based cross-sectional study on a representative population of Chennai in southern India. Fruit and vegetable intake (g/d) was measured using a validated semi-quantitative FFQ. Linear regression analysis revealed that after adjusting for potential confounders such as age, sex, smoking, alcohol, BMI and total energy intake, the highest quartile of fruit and vegetable intake (g/d) showed a significant inverse association with systolic blood pressure ($\beta = -2.6$ (95% CI $-5.92, -1.02$) mmHg; $P=0.027$), BMI ($\beta = -2.3$ (95% CI $-2.96, -1.57$) kg/m²; $P<0.0001$), waist circumference ($\beta = -2.6$ (95% CI $-3.69, -1.46$) cm; $P<0.0001$), total cholesterol ($\beta = -50$ (95% CI $-113.9, -13.6$) mg/l; $P=0.017$) and LDL-cholesterol concentration ($\beta = -55$ (95% CI $-110.8, -11.1$) mg/l; $P=0.039$) when compared with the lowest quartile. A higher intake of fruit and vegetables explained 48% of the protective effect against CVD risk factors. Increased intake of fruits and vegetables could play a protective role against CVD in Asian Indians who have high rates of premature coronary artery disease.

Fruit and vegetables: Cardiovascular risk factors: Non-communicable diseases: Diabetes: Asian Indians

Although CVD was earlier more prevalent in developed countries, its burden is now higher in developing countries¹. According to recent projections, by the year 2020, 6.4 million deaths due to CVD could occur in developing countries in the age group of 30–69 years². Asian Indians are known to have a greater susceptibility to type 2 diabetes and premature coronary artery disease compared with Europeans^{1,3,4}. Like other developing countries in transition, increased life expectancy, urbanisation, changes in dietary patterns from 'traditional' to 'Western' and physical inactivity due to increased affluence are some of the important contributors to the rapidly rising prevalence of cardiovascular risk factors in urban Indians⁵.

Diet has long been linked to the development of obesity, diabetes and CVD⁶ and dietary modification is one of the cornerstones of chronic disease prevention. Examination of single nutrients in relation to CVD risk may ignore the biochemical complexity of whole foods. In addition, dietary advice becomes easier to understand and follow if provided in terms of whole foods. The beneficial effect of diets rich in fruits and vegetables has been well recognised for the prevention of chronic diseases, especially CVD, as they contain substantial amounts of nutrients such as folate, antioxidant vitamins, K and dietary fibre^{7–9}.

The World Health Report¹⁰ estimates that low fruit and vegetable intake contributes to approximately 2.7 million deaths (4.9%) per year from chronic diseases and causes about 31% IHD and 11% stroke worldwide. Indeed low fruit and vegetable intake is ranked as the seventh main risk factor among causes of disability-adjusted life-years in developing countries with low mortality.

Several studies in the West have reported on the beneficial effect of fruit and vegetable consumption with respect to CVD risk^{11–13}. There is an urgent need for such data from India where rapid nutritional transition is ongoing due to urbanisation and globalisation leading to increasing levels of potentially reversible CVD risk factors¹. Furthermore, a clear understanding of the relationship between fruit and vegetable intake and CVD risk could also provide a more direct scientific basis for practical dietary guidelines for the prevention of CVD. Therefore, in the present cross-sectional study, we sought to evaluate the association of fruit and vegetable intake with cardiovascular risk factors such as obesity, hypertension, fasting plasma glucose and dyslipidaemia in urban Asian Indians in southern India.

Abbreviation: CURES, Chennai Urban Rural Epidemiological Study.

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Materials and methods

Sampling

Study subjects were recruited from the Chennai Urban Rural Epidemiology Study (CURES), an ongoing epidemiological study conducted on a representative population of Chennai city (formerly Madras) in southern India with a population of about 5 million individuals. The methodology of the study has been published elsewhere¹⁴. Our website <http://www.drmoahansdiabetes.com> (under the link 'publications') provides details of the sampling frame. Briefly, the city of Chennai is divided into 155 corporation wards representing a socio-economically diverse group. In Phase 1 of CURES, individuals from forty-six corporation wards were screened by a systematic sampling technique. The sample distribution in each ward within these zones is based on the proportion of their population in that particular zone. A probabilistic proportionate sampling was adopted to select the number of individuals seen in each ward. Furthermore, within each ward, every third lane or road, following the right-hand rule, was surveyed. A total of 26 001 individuals aged ≥ 20 years were screened.

Phase 2 of CURES deals with studies on the prevalence of microvascular and macrovascular complications of diabetes. Phases 1 and 2 are not discussed further in the present article.

In phase 3 of CURES, every tenth subject recruited in phase 1 (n 2600) was invited to our centre for detailed anthropometric measurements and biochemical tests and every alternate individual from the group (n 1300) was invited for detailed dietary studies. Of these, 1143 subjects participated in the present study (response rate 87.9% (1143 out of 1300 individuals)). This sample is thus representative of the Chennai population. Subjects with self-reported history of diabetes or hypertension or CVD or on drug therapy for dyslipidaemia were excluded (n 160). The remaining 983 subjects were included in the present study.

All study subjects underwent an oral glucose tolerance test using a glucose load of 75 g, except self-reported diabetic subjects, for whom fasting venous plasma glucose was measured. The fasting blood sample was taken after ensuring 8 h overnight fasting, for estimation of plasma glucose and serum lipids using a Hitachi 912 Autoanalyser (Roche Diagnostics GmbH, Mannheim, Germany) utilising kits supplied by Boehringer Mannheim (Mannheim, Germany). Anthropometric measurements including weight, height, waist and hip measurements were obtained using standardised techniques¹⁴. Blood pressure was recorded in the right upper limb in sitting position to the nearest 2 mmHg using an Hg sphygmomanometer (Diamond Deluxe BP apparatus; Industrial Electronic & Allied Products, Pune, India). Two readings were taken 5 min apart, and the mean of two was taken as the blood pressure. Demographic and socio-economic characteristics, medical history, medications, family history of diseases, smoking status (current smokers: yes or no) and alcohol consumption (current drinker: yes or no) were also obtained¹⁴. The institutional ethical committee approval was obtained and informed consent was obtained from all study subjects.

Definitions

Newly diagnosed diabetes. Diagnosis of 'newly detected diabetic subjects' was based on WHO consulting group criteria,

i.e. fasting plasma glucose ≥ 1260 mg/l (7 mmol/l) and/or 2 h post-load plasma glucose ≥ 2000 mg/l (≥ 11.1 mmol/l)¹⁵.

Newly diagnosed hypertension. Hypertension was diagnosed based on systolic blood pressure ≥ 130 mmHg or diastolic blood pressure of ≥ 85 mmHg¹⁶.

Dyslipidaemia. This was defined using National Cholesterol Education Program Adult Treatment Panel¹⁷ guidelines as follows.

Hypercholesterolaemia was diagnosed if serum cholesterol levels were ≥ 2000 mg/l (≥ 5.2 mmol/l).

Hypertriglycerolaemia was diagnosed if serum TAG levels were ≥ 1500 mg/l (≥ 1.7 mmol/l).

Low high-density-lipoprotein-cholesterol was diagnosed if HDL-cholesterol levels were < 400 mg/l for men and < 500 mg/l for women.

High low-density-lipoprotein-cholesterol was diagnosed if LDL-cholesterol levels were ≥ 1300 mg/l.

Dietary assessment

Usual dietary intake was assessed by using a validated interviewer-administered semi-quantitative FFQ (meal-based)¹⁸. The nutritionists responsible for the data collection were well trained in the methodology to be used before fieldwork was started. Data were collected by one-to-one interview after obtaining informed consent. The FFQ took about 20–30 min to complete. This FFQ contains 222 items that included commonly available and eaten fruits (twenty fruits including both citrus and non-citrus variety) and twenty-five vegetables in the form of both raw and cooked foods including cruciferous (cabbage, broccoli, cauliflower), dark yellow (excluded tubers), green leafy vegetables (amaranth, spinach, palak, drumstick leaves (*Moringa oleifera*), mint, coriander) and other vegetables (egg plant, mixed vegetables, drumstick, mushrooms, ladies' fingers (okra), knol-knol, chow-chow, gourd varieties). Data on the seasonal availability of fruits and vegetables were obtained from local wholesale vendors¹⁸. These values were used to convert reported seasonal intake into average intake throughout the year (For example, mangoes are seasonal and are available for the period of 3 months. Suppose if the respondent reported consuming one medium-size mango once-weekly, the nutritionist will convert it to yearly as twelve mangoes (with 4 weeks in each month).)

For each fruit or vegetable, a usual serving size was specified and the individuals were asked to estimate the usual frequency (number of times per d, week, month or year, or never) on average, during the previous year they had consumed that amount. Common household measures such as household cups, bowls, ladles, spoons (for the cooked foods such as vegetables), wedges (to estimate slices of cakes and fruits), circles of different diameter (to estimate the portion size of foods such as paratas or chapatis) and a visual atlas of different sizes of fruits (small, medium, large) were shown to assist the individuals in the estimating process. Frequencies and serving size of the individual food items were converted to average daily intake (g/d) of each fruit and vegetable item for each subject. The average daily intakes of individual foods were summed to compute total fruit and vegetable intake (g/d). Information on total energy was obtained using the same FFQ. A detailed description of the reproducibility and validity of the FFQ has been published elsewhere¹⁸. Validity of the

FFQ has been documented by comparisons with multiple 24 h recalls collected at 2-monthly intervals for a period of 1 year covering all four seasons. This included four weekdays and two weekends to capture variability in weekend *v.* weekday food intakes. The energy-adjusted deattenuated Pearson correlation coefficients for the response to the 222-item questionnaire, for fruits and vegetables from the questionnaire compared with six 24 h recalls, averaged 0.28.

Reported individual food items were converted to average daily intake of each fruit and vegetable item for each participant using an in-house EpiNu India[®] database and software (Nutritional Epidemiology, Food and Nutrient database, version 1.0), developed and launched by the Department of Nutrition and Dietetics Research of Madras Diabetes Research Foundation. This database contains comprehensive data for 1500 recipes (both commercial and non-commercial) and sixty nutrients. The average daily intakes of individual food items were combined to compute total fruit and vegetable intake.

Statistical analysis

All analyses were conducted using the statistical software package SPSS (version 10.0; SPSS, Inc., Chicago, IL, USA). Subjects were divided into quartiles of fruit and vegetable intake (g/d). The mean of each was reported and compared for the descriptive characteristic. Values are expressed as means and standard deviations. One-way ANOVA or Student's *t* test as appropriate was used to compare continuous variables, and the χ^2 test was used to compare the proportions among groups. To investigate whether the clustering of CVD risk factors was significantly related to fruit and vegetable intake, we computed Z scores by sex for all nine risk factor

variables (systolic blood pressure, diastolic blood pressure, BMI, waist circumference, fasting plasma glucose, total serum cholesterol, TAG, HDL-cholesterol and LDL-cholesterol). Z scores were computed as the number of SD units from the sample mean, i.e. $Z = ((\text{individual value} - \text{the sex-specific mean value}) / \text{sex-specific SD})$. The HDL-cholesterol Z score was multiplied by -1 to indicate higher cardiovascular risk with increasing value. The sum of all Z scores indicates the cluster of cardiovascular risk factors. Regression analysis was carried out using cardiovascular risk factors as dependent variables and the first and fourth quartile of fruit and vegetable intake (g/d) as the independent variable with adjustment for potential confounders such as age (years), sex (dichotomous), BMI (continuous variable), current smoking (yes or no), alcohol (yes or no) and total energy intake (kJ). All tests of significance were two-tailed and a *P* value of <0.05 was considered significant.

Results

The baseline characteristics of the study participants by sex are presented in Table 1. The ages of the men and the women were 40.2 (SD 12.6) and 38.8 (SD 11.5) years respectively. Men had significantly lower BMI ($P=0.003$) and HDL-cholesterol concentration ($P<0.0001$) but higher systolic blood pressure ($P=0.009$), diastolic blood pressure ($P<0.0001$), waist circumference ($P<0.0001$), fasting blood sugar ($P=0.055$) and serum TAG ($P<0.0001$) compared with women. Similarly men had higher prevalence of hypertension ($P=0.023$) and dyslipidaemia ($P<0.0001$) than women. No significant mean differences were observed in the fruit and vegetable intake (g/d) between the sexes. Fruit and vegetable intake did not differ between non-vegetarians

Table 1. General and clinical characteristics of the representative population of 983 urban subjects (Mean values and standard deviations or proportions)

Variables	Males (n 455)		Females (n 528)		<i>P</i> *
	Mean	SD	Mean	SD	
Participants (%)	46.3		53.7		–
Age (years)	40.2	12.6	38.8	11.5	NS
BMI (kg/m ²)	22.8	3.6	23.4	4.1	0.003
Systolic blood pressure (mmHg)	118.7	16.6	115.8	18.2	0.009
Diastolic blood pressure (mmHg)	74.5	11.4	71.8	11.2	<0.0001
Waist circumference (cm)	84.7	11.0	81.0	10.7	<0.0001
Fasting blood glucose (mg/l)	914	271	883	234	0.055
Serum total cholesterol (mg/l)	1766	366	1789	373	NS
Serum TAG (mg/l)	1333	849	1127	690	<0.0001
Serum HDL-cholesterol (mg/l)	400	103	447	94	<0.0001
Serum LDL-cholesterol (mg/l)	1099	307	1117	322	NS
Prevalence of newly diagnosed diabetes (%)	9.2		6.8		NS
Prevalence of newly diagnosed hypertension (%)	30.1		24.2		0.023
Prevalence of newly diagnosed dyslipidaemia (%)	91.2		55.7		<0.0001
Fruits and vegetables (g/d)	259.6	103.8	270.4	126.2	NS
Total energy (kJ/d)	11 159	2573	9887	2201	<0.0001
Total energy (kcal/d)	2667	615	2363	526	<0.0001
Current cigarette smoking (%)	43.7		0		<0.0001
Alcohol consumption (%)	51.2		0.6		<0.0001
CVD risk factors (Z score)†	0.25	4.8	–0.23	4.7	NS

* For continuous characteristics, performed using Student's *t* test. For categorical tests, the χ^2 test for trend was used.

† CVD risk factor score was calculated as the sum of Z scores for systolic blood pressure, diastolic blood pressure, waist circumference, BMI, fasting plasma glucose, total cholesterol, TAG, LDL-cholesterol and HDL-cholesterol.

(*n* 897; 263 (SD 111.1) g/d) and vegetarians including ovo-vegetarians (*n* 86; 278.7 (SD 143.5) g/d; *P*=0.357). The cardiovascular risk factor score was higher in men (0.25 (SD 4.8)) compared with women (-0.23 (SD 4.7)).

Fruit and vegetable consumption

The clinical characteristics of the study participants by quartiles of fruit and vegetables are presented in Table 2. Intake of fruit and vegetables ranged from 141 g/d in the lowest quartile to 418 g/d in the highest quartile. A higher intake of fruit and vegetables was associated with younger age (*P* for trend <0.001), lower prevalence of hypertension (*P* for trend =0.005) and dyslipidaemia (*P* for trend <0.0001). Systolic blood pressure (*P* for trend <0.001), diastolic blood pressure (*P* for trend =0.002), BMI (*P* for trend=0.004), serum cholesterol (*P* for trend <0.001), serum LDL-cholesterol (*P* for trend <0.0001) and waist circumference (*P* for trend <0.0001) were significantly lower in those in the higher quartiles of fruit and vegetable intake. CVD risk score (*P* for trend <0.0001) was inversely related to higher fruit and vegetable intake (g/d).

Association between fruit and vegetable intake with cardiovascular risk factors

In a regression analysis model, we observed a significant inverse association in cardiovascular risk factors and fruit and vegetable intake (g/d) (Table 3). Higher intake of energy-adjusted fruit and vegetable intake showed an significant inverse association with systolic blood pressure ($\beta = -5.4$ (95 % CI -8.89, -1.944) mmHg; *P*=0.002), diastolic blood pressure ($\beta = -3.4$ (95 % CI -5.86, -1.483) mmHg;

P<0.0001), BMI ($\beta = -2.0$ (95 % CI -2.74, -1.32) kg/m²; *P*<0.0001), waist circumference ($\beta = -7.9$ (95 % CI -9.87, -5.96) cm; *P*<0.0001), serum total cholesterol ($\beta = -77$ (95 % CI -140.3, -13.0) mg/l; *P*=0.019), LDL-cholesterol ($\beta = -79$ (95 % CI -134.1, -24.8) mg/l; *P*=0.004) and HDL-cholesterol ($\beta = 29$ (95 % CI 10.8, 40.7) mg/l; *P*=0.002) when compared with the lowest quartile (model 1). Adjusting for age and sex (model 2) did not alter the significant association for systolic blood pressure ($\beta = -4.5$ (95 % CI -7.76, -1.29) mmHg; *P*=0.006), diastolic blood pressure ($\beta = -3.2$ (95 % CI -5.33, -1.09) mmHg; *P*=0.003), BMI ($\beta = -2.3$ (95 % CI -2.91, -1.52) kg/m²; *P*<0.0001), waist circumference ($\beta = -7.6$ (95 % CI -9.58, -5.69) cm; *P*<0.0001), serum total cholesterol ($\beta = -73$ (95 % CI -134.5, -11.4) mg/l; *P*=0.020), HDL-cholesterol ($\beta = 26$ (95 % CI 8.8, 44.0) mg/l; *P*=0.003) and LDL-cholesterol ($\beta = -77$ (95 % CI -130.6, -22.5) mg/l; *P*=0.006). Further, introducing smoking and alcohol (model 3) into the model did not alter the results. Though there was a strong association for consumption of fruit and vegetables with diastolic blood pressure this became insignificant after adjustment for BMI (model 4) but a significant inverse association persisted for systolic blood pressure ($\beta = -2.6$ (95 % CI -5.92, -1.02) mmHg; *P*=0.027), waist circumference ($\beta = -2.6$ (95 % CI -3.69, -1.46) cm; *P*<0.0001), serum total cholesterol ($\beta = -50$ (95 % CI -113.9, -13.6) mg/l; *P*=0.017) and LDL-cholesterol ($\beta = -55$ (95 % CI -110.8, -11.1) mg/l; *P*=0.039) with fruit and vegetable intake (g/d). Higher fruit and vegetable intake (g/d) was inversely related to the CVD risk score ($\beta = -1.0$ (95 % CI -1.74, -0.32); *P*=0.004) even after adjusting for all the confounding factors. The highest quartile of fruit and vegetables explained 48 % of the protective effect against CVD risk factors compared with the lowest quartile.

Table 2. Description of cardiovascular risk factors according to quartiles (Q) of fruit and vegetable intake (g/d) of 983 subjects (Mean values and standard deviations or proportions)

Variables	Fruit and vegetable intake in quartiles (g/d)								<i>P</i> for trend*
	Q1 (lowest)		Q2		Q3		Q4 (highest)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Quartile range for intake (g/d)	30–186		186–248		248–327		327–1026		–
Mean quartile intake (g/d)	141	–	215	–	287	–	418	–	–
Subjects (n)	245		246		246		246		–
Age (years)	41.8	13.5	39.6	11.9	38.2	11.2	38.5	11.2	<0.001
BMI (kg/m ²)	23.4	4.1	23.3	3.8	22.8	3.6	22.5	4.2	0.004
Smoking (%)	21.2		23.2		21.1		15.9		0.114
Alcohol (%)	20.4		32.5		21.1		22		0.577
Systolic blood pressure (mmHg)	120.4	20.8	117.5	16.1	115.1	16.1	115.5	16.3	<0.001
Diastolic blood pressure (mmHg)	74.6	12.2	73.6	11.2	72.4	10.6	71.7	11.4	0.002
Waist circumference (cm)	84.8	10.7	84.4	10.1	81.7	10.3	80	12	<0.0001
Fasting blood glucose (mg/l)	919	304	914	269	871	166	887	249	0.058
Serum total cholesterol (mg/l)	1814	349	1824	425	1750	357	1724	336	0.001
Serum TAG (mg/l)	1232	673	1306	821	1178	792	1173	798	0.168
Serum HDL-cholesterol (mg/l)	418	96	423	96	428	109	432	104	0.116
Serum LDL-cholesterol (mg/l)	1150	292	1140	357	1086	305	1058	295	<0.0001
Newly diagnosed diabetes (%)	9		9.8		4.1		8.9		0.311
Newly diagnosed hypertension (%)	32.2		29.7		23.6		22.4		0.005
Newly diagnosed dyslipidaemia (%)	77.1		77.2		69.9		64.2		<0.0001
CVD risk factors (Z score)†	1.06	4.7	0.65	4.8	-0.64	4.3	-1.00	4.8	<0.0001

* For continuous characteristics, performed using one-way ANOVA. For categorical tests, the χ^2 test for trend was used.

† CVD risk factor score was calculated as the sum of Z scores for systolic blood pressure, diastolic blood pressure, waist circumference, BMI, fasting plasma glucose, total cholesterol, TAG, LDL-cholesterol and HDL-cholesterol.

Table 3. Multivariate adjusted association between fruit and vegetable intake (g/d) and common cardiovascular risk factors*
(Regression coefficients and 95 % confidence intervals)

	First quartile v. fourth quartile of fruit and vegetable intake (g/d)†											
	Model 1			Model 2			Model 3			Model 4		
	β	95 % CI	P	β	95 % CI	P	β	95 % CI	P	β	95 % CI	P
Systolic blood pressure (mmHg)	-5.4	-8.89, -1.94	0.002	-4.5	-7.76, -1.29	0.006	-4.6	-7.80, -1.3	0.006	-2.6	-5.92, -1.02	0.027
Diastolic blood pressure (mmHg)	-3.4	-5.86, -1.48	<0.0001	-3.2	-5.33, -1.09	0.003	-3.2	-5.35, -1.08	0.003	-1.6	-3.80, 0.530	0.138
BMI (kg/m ²)	-2.0	-2.74, -1.32	<0.0001	-2.3	-2.91, -1.52	<0.0001	-2.3	-2.96, -1.57	<0.0001	-	-	-
Waist circumference (cm)	-7.9	-9.87, -5.96	<0.0001	-7.6	-9.58, -5.69	<0.0001	-7.9	-9.73, -5.84	<0.0001	-2.6	-3.69, -1.46	<0.0001
Fasting blood sugar (mg/l)	-36	-87.5, 15.9	0.175	-31	-82.9, 21.0	0.242	-32	-83.9, 20.4	0.231	-19	-74.0, 34.5	0.474
Serum total cholesterol (mg/l)	-77	-140.3, -13.0	0.019	-73	-134.5, -11.4	0.020	-75	-136.6, -13.3	0.014	-50	-113.9, -13.6	0.017
Serum TAG (mg/l)	-131	-266.4, 5.4	0.060	-114	-250.1, 21.8	0.100	-118	-254.3, 19.2	0.092	-45	-185.6, 95.3	0.527
LDL-cholesterol (mg/l)	-79	-134.1, -24.8	0.004	-77	-130.6, -22.5	0.006	-78	-132.1, -23.8	0.014	-55	-110.8, -11.1	0.039
HDL-cholesterol (mg/l)	29	10.8, 40.7	0.002	26	8.8, 44.0	0.003	27	8.9, 44.3	0.003	14	-4.4, 31.6	0.139
CVD risk factors (Z score)‡	-2.7	-3.59, -1.83	<0.0001	-2.6	-3.42, -1.75	<0.0001	-2.6	-3.5, -1.79	<0.0001	-1.0	-1.74, -0.32	0.004

* All models were adjusted for total energy intake (kJ). Model 1 was unadjusted; model 2 was adjusted for age (years) and sex (dichotomous); model 3 was adjusted for model 2 and smoking (yes or no) and alcohol (yes or no); model 4 was adjusted for model 3 and BMI (continuous variable).

† First quartile < 180 g/d = 0 v. fourth quartile > 327 g/d = 1.

‡ CVD risk factor score was calculated as the sum of Z scores for systolic blood pressure, diastolic blood pressure, waist circumference, BMI, fasting plasma glucose, total cholesterol, TAG, LDL-cholesterol and HDL-cholesterol.

Discussion

CVD is becoming the leading cause of mortality and morbidity in many developing countries, especially in India. Levels of various CVD risk factors are rising with the rapid nutritional and epidemiological transition in these countries as reflected by higher diabetes prevalence, increased cholesterol, blood pressure levels and greater obesity rates¹. There is also increasing evidence that energy-dense foods usually associated with lower fruit and vegetable intake increase the risk of CVD¹⁹.

In the present cross-sectional study, a higher fruit and vegetable intake was inversely associated with several risk factors for CVD such as waist circumference, BMI, total cholesterol and LDL-cholesterol concentration, independent of age, sex, smoking status, alcohol, BMI and total energy intake. Overall fruit and vegetable intake explained 48% of the protective effect against CVD risk factors. To our knowledge, this is the first epidemiological study from India directly showing a link between decreasing fruit and vegetable intake individually with virtually all CVD disease risk factors.

Obesity, particularly abdominal obesity, is a well-known risk factor for CVD and type 2 diabetes; Asian Indians are known to have lower BMI than Europeans²⁰. However, for any given BMI, Asian Indians have greater waist:hip ratios^{20,21} and abdominal fat than Europeans. Studies suggest that a diet rich in dietary fibre is protective against obesity, as obesity is less common in populations that consume a high-fibre diet and more prevalent in populations that consume a low-fibre diet²². Although earlier studies from India have assessed the effect of dietary fat and obesity, limited data are available on the association of fruit and vegetable intake with obesity (including central obesity) in this population. In the present study, fruit and vegetable intake was inversely correlated to waist circumference and BMI and this is reflected in the lower CVD risk factor prevalence. Similar results were also reported in other epidemiological studies²³. The mechanisms underlying such an effect are possibly due to high fibre intake, which further reduces the total energy intake and is associated with increased fat excretion²⁴, improved insulin sensitivity and reduced insulinaemia²³.

Diets rich in vegetables and fruits have been shown to control and prevent high blood pressure in a multicentre clinical trial with a heterogeneous population²⁵. In the Chicago Western Electric Study, fruit and vegetable intake was inversely associated with an age-related rise in blood pressure²⁶. In a cross-sectional study among 4393 individuals in Spain, a high fruit and vegetable intake was inversely associated with blood pressure²⁷. Similar results were also reported in a cross-sectional study among 1497 individuals in Kerala, South India²⁸. This inverse relationship was also evident from the present study where the mean systolic blood pressure was 4.9 mmHg and diastolic blood pressure 2.9 mmHg lower for those with the highest consumption of fruit and vegetable intake. These findings suggest that the adoption of diets rich in fruits and vegetables might potentially shift the population distribution of blood pressure downward and thereby prevent CVD.

Serum total cholesterol and LDL-cholesterol are well-known risk factors for CVD³. There is also evidence to show that diets rich in fruits and vegetables and low-fat

dairy products and reduced in saturated fat, total fat and cholesterol content (dietary approaches to stop hypertension (DASH) diet) substantially lower the total and LDL-cholesterol concentration²⁹. Fornes *et al.*³⁰ reported in a cross-sectional study that the intake of fruits and vegetables was inversely correlated with LDL-cholesterol. Other investigators³¹ also reported on the beneficial effect of fruit and vegetable intake on LDL-cholesterol concentration. The present findings are also consistent with these reports, as the levels of both total and LDL-cholesterol were lower in the higher quartiles of fruit and vegetable intake.

Viswanathan & Mohan³² showed significant reduction in serum cholesterol among diabetic patients with a high-carbohydrate, high-fibre diet and these effects were sustained for a long period of time³³. Diets rich in fruits and vegetables are good sources of dietary fibre, which may indirectly lower serum cholesterol levels. In addition, antioxidants such as vitamin C and β -carotene may help to reduce lipid oxidation of LDL-cholesterol, thereby preventing the development and progression of atherogenesis^{34–36}.

Studies on dietary patterns test the hypothesis that a combination of foods and their nutrients, rather than the individual constituents of a diet, confers or reduces the disease risk. The biological mechanisms responsible for the beneficial effects of fruits and vegetables on CVD risk are therefore likely to be multiple. Besides their contribution to low energy, high fibre content and low glycaemic load, fruits and vegetables are also rich in phytochemicals, antioxidants and other micronutrients, all of which could be beneficial in reducing the risk of CVD³⁷.

The WHO³⁸ recommends a population goal of consumption of a minimum 400 g fruits and vegetables per d for the prevention of chronic non-communicable diseases. The mean intake of fruits and vegetables in the present study was 265 g/d, which was much lower than the recommended intake by the WHO. Though India has a prominent share in the global production of fruits and vegetables and a significant proportion of the population is vegetarian³⁹, this does not seem to be reflected in an increase in the consumption of fruits and vegetables – perhaps the result of export and as it is not affordable by a large section of the population⁴⁰. This might be one of the less-emphasised reasons for the increased susceptibility of Asian Indians to diabetes and premature CVD^{4,5,41}.

One of the limitations of the study is that being a cross-sectional one, it is not the appropriate design to assess the cause and effect between diets and CVD. Longitudinal studies or clinical trials are best suited to evaluate the role of fruit and vegetables in the development of, or protection against, CVD and its risk factors. Physical activity was also not controlled in the present study, but could have, at least in part, been adjusted by adjusting for BMI and total energy intake.

The present study, however, has several strengths. We investigated the association in a relatively large population representative of the overall population of Chennai, which is in turn representative of urban India and hence the results can be extrapolated at least to urban India. The study used an FFQ, to measure the dietary intake of fruits and vegetables, which is considered a better method than a single 24 h recall or even a 7 d food record⁴². The FFQ used in the present study covered seasonality and has been validated and published¹⁸. In addition, CVD risk Z score, which we used to define

clustering of CVD risk factors on a continuous scale, is statistically more sensitive and less error prone compared with other approaches⁴³. Finally, use of regression analysis in the present study allowed for simultaneous adjustment of several confounding variables. The present study thus offers valuable new data from India on the role of fruit and vegetable intake and the prevalence of CVD risk factors in a population at very high risk of CVD. Further epidemiological studies are needed to further elucidate the type and amount of fruit and vegetables that are most effective in the prevention of chronic diseases such as diabetes and CVD in South Asians in general and Asian Indians in particular.

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