

Original Article

Association of dietary patterns and dietary diversity with cardiometabolic disease risk factors among adults in South Asia: The CARRS study

Deksha Kapoor MSc¹, Romaina Iqbal PhD², Kalpana Singh MSc³, Lindsay M Jaacks PhD⁴, Roopa Shivashankar MD⁵, Vasudevan Sudha MSc⁶, RM Anjana MD⁶, Masood Kadir MPH, MOHS², Viswanathan Mohan MD, PhD, DSc⁶, Mohammed K Ali MD, MBA⁷, KMV Narayan MD, MBA⁷, Nikhil Tandon MD, PhD¹, Dorairaj Prabhakaran MD, DM⁵, Anwar T Merchant ScD, DMD⁸

¹All India Institute of Medicine, New Delhi, India

²Aga Khan University, Karachi, Pakistan

³Public Health Foundation of India, India

⁴Department of Global Health and Population, Harvard University, Boston, MA, USA

⁵Public Health Foundation of India and Centre for Chronic Disease Control, Gurgaon, India

⁶Madras Diabetes Research Foundation, Chennai, India

⁷Department of Global Health, Emory University, Atlanta, GA, USA

⁸Department of Epidemiology and Biostatistics, University of South Carolina, Columbia

Background and Objectives: To investigate the association of dietary patterns and dietary diversity with cardio-metabolic disease risk factors among South Asians. **Methods and Study Design:** In a population based study conducted in 2010-11, we recruited 16,287 adults aged >20 years residing in Delhi, Chennai, and Karachi. Diet was assessed using an interviewer-administered 26-item food frequency questionnaire. Principal component analysis identified three dietary patterns: Prudent, Indian, and Non-Vegetarian. We also computed a dietary diversity score. Multinomial and binary logistic regressions were used to calculate adjusted prevalence (95% confidence intervals) of cardio-metabolic disease risk factors across quartiles of dietary pattern and dietary diversity scores. **Results:** The adjusted prevalence of diagnosed diabetes was lower among participants in the highest versus lowest quartile of the Prudent Pattern (4.7% [3.8–5.6] versus 10.3% [8.5–12.0]), and the Indian Pattern (4.8% [3.7–5.9] versus 8.7% [6.7–10.6] in highest versus lowest quartile, respectively). Participants following the Indian Pattern also had lower adjusted prevalence of diagnosed hypertension (7.0% [5.4–8.5] versus 10.6% [8.6–12.5] in highest versus lowest quartile, respectively). Participants in the highest versus lowest quartile of the dietary diversity score had a lower adjusted prevalence of diagnosed diabetes (4.1% [3.0–5.2] versus 8.2% [7.1–9.3]), diagnosed hypertension (6.7% [5.3–8.1] versus 10.3% [9.1–11.5]), and undiagnosed hypertension (14.2% [12.0–16.4] versus 18.5% [16.9–20.1]). **Conclusions:** High dietary diversity appears to be protective against cardio-metabolic disease risk factors in this urban cohort of South Asian adults. Further investigation to understand the underlying mechanism of this observation is warranted.

Key Words: principal component analysis, prudent diet, hypertension, diabetes, India, Pakistan

INTRODUCTION

Around the world, national dietary guidelines are beginning to recommend dietary patterns rather than specific nutrient targets to promote health and prevent disease. Some examples of this include the 2015-2020 Dietary Guidelines for Americans, which recommend three dietary patterns—a healthy American diet, a vegetarian diet, and a Mediterranean-style diet¹ and the 2014 Brazilian Dietary Guidelines, which state that choosing healthy foods and meals is fundamental to improving diet and nutrition.² This transition is supported by accumulating evidence that dietary patterns are more predictive of clinical outcomes than single nutrients with respect to chronic diseases.³ However,

there is a dearth of evidence on dietary patterns and disease risk in South Asian populations, who are at increased risk of cardio-metabolic diseases.⁴⁻⁷

With respect to cardio-metabolic disease risk, several

Corresponding Author: Deksha Kapoor, Department of Endocrinology and Metabolism, All India Institute of Medical Sciences, New Delhi 110029, India.

Tel: +91-9818843605; Fax: +91-11- 26588663.

Email: deksha.kapoor@gmail.com

Manuscript received 13 October 2017. Initial review completed 07 April 2018. Revision accepted 17 July 2018.

doi: 10.6133/apjcn.201811_27(6).0021

large prospective studies in the U.S. population have reported that the Western dietary pattern is associated with increased risk and that the prudent dietary pattern is associated with decreased risk for cardiovascular disease (CVD)^{4,6} and diabetes.⁸ Several other Western studies⁹⁻¹² have focused on Western-dietary patterns associated with risk factors for diabetes, CVD, and metabolic syndrome.¹³ The focus on dietary patterns has been fruitful in demonstrating the powerful protective associations of healthy or prudent dietary patterns, and the higher risk associations of Western or meat and refined grains patterns.¹⁴

In addition to dietary patterns, dietary diversity as an indicator of overall diet quality has been associated with increased intakes of fiber, vitamin C, and calcium,¹⁵ all of which protect against CVD.¹⁶⁻¹⁹ Studies have shown a significant correlation between dietary diversity and CVD risk,²⁰ metabolic syndrome, arterial wall indices namely, aorto iliac compliance measured through pulse wave damping and proximal resistance at common femoral and posterior tibia,²¹ and hypertension.²² However, there is limited data on these associations in South Asian populations. The aim of this study was to investigate the associations of dietary patterns and dietary diversity with cardio-metabolic disease risk factors among South Asians.

PARTICIPANTS AND METHODS

Sample

The CARRS (Centre for cArdiometabolic Risk Reduction in South Asia) surveillance study is an ongoing cohort on cardio-metabolic disease and its associated risk factors conducted in three large urban centers: Chennai and Delhi in India, and Karachi in Pakistan.²³ Complex, multi-stage, probability-based sampling was used to select households and individuals that were representative of the cities involved. Briefly, the most recent census (the 2001 Census in India and 1998 Census in Pakistan) was used to develop the CARRS sampling frame. Wards were the primary sampling units in Chennai and Delhi, whereas Census Enumeration Blocks (CEBs) were the primary sampling units in Karachi. Wards and CEBs were randomly selected from census lists for inclusion, then manual listing and mapping of all households in each CEB was done prior to randomly selecting households for inclusion. Two participants, one male and one female, aged 20 years or older, were selected from each household using either the 2002 Health Information National Trends Study method (for households with 1-2 adults) or the Kish method (for households with >2 adults). A total of 16,287 men and non-pregnant women over 20 years old were enrolled in 2010-11.

Data on socio-demographics, medical history, diet, and other lifestyle behaviours were collected by trained field workers through a questionnaire in their local languages at their households. Questions were derived from questionnaires used in the Chennai Urban Population Study, the Chennai Urban Rural Epidemiological Study, and the Sentinel Surveillance Study.²³ Time spent sitting was estimated using the short form of the International Physical Activity Questionnaire.²⁴ The response rate for questionnaire completion was 94.7% and for bio specimen collection was 84.3%.

All procedures were approved by the ethics review committees at Emory University (IRB00044159), Public

Health Foundation of India (IRB00006658), All India Institute of Medical Sciences (IEC/NP-17/07.09.09), Aga Khan University (1468-CHS-ERC-2010), and Madras Diabetes Research Foundation (IRB00002639). Written informed consent was obtained from all participants.

Dietary pattern assessment

A 26-item food frequency questionnaire (FFQ) adapted from the 19-item INTERHEART study²⁵ was used to assess dietary intake. A direct comparison of the CARRS FFQ and INTERHEART FFQ is provided in Supplemental table 1. Information on portion size was not collected but frequency of consumption was recorded (never or less than once a month, per month, per week, or per day) over the past year. All frequency variables were standardized to consumption per day. Dietary patterns were derived using (1) PCA and (2) an a priori defined dietary diversity score. PCA was applied to the 26 food groups from the FFQ using the "pca" command in Stata version 12.1 (StataCorp, College Station, TX, USA) with a varimax rotation to improve pattern interpretation. Evaluation of the Scree plot (Supplemental figure 1) for components with eigenvalues >1 was used to identify the number of components to retain.

The a priori dietary diversity score indicates the number of different food groups that participants reported consuming. For calculating the score, the items in the FFQ were combined into eight food groups: grains, vegetables, fruits, legumes, non-vegetarian (meat, poultry, and fish), milk and milk products, sugar, and solid fats and oils. If the food group was consumed monthly or never it was given a score of 0; if consumed less than one time per week but more than one time per month it was given a score of 1; and if consumed at least once per week it was given a score of 2. A participant's overall score was the sum of the scores for the eight food groups (maximum value of 16, representing the highest dietary diversity). This is based on the dietary variety score of Wahlqvist et al²¹ and the dietary diversity score of Newby et al.²⁶

Outcome assessment

We evaluated four outcomes: diabetes, hypertension, overweight/obesity, and history of CVD. Standardized procedures were used to measure weight, height, and blood pressure. Specifically, weight was measured to the nearest 0.1 kg (electronic body-composition analyser, Tanita BC-418 in Delhi and Chennai, and Tanita BC-545 in Karachi, Tanita Co, Tokyo, Japan), height to the nearest 0.1 cm (portable stadiometer, SECA Model 213, SecaGmbH Co, Hamburg, Germany), and waist and hip circumferences to the nearest 0.1 cm (non-stretch measuring tape, Gulick II, Country Technology, Gays Mills, WI) based on the U.S. National Health and Nutrition Examination Survey (NHANES-III) protocol.²⁷ Body mass index (BMI) was calculated as weight (kg) divided by height-squared (m²). Obesity including overweight was defined as BMI ≥ 25 kg/m².²⁸ Blood pressure was measured twice after 5 minutes in a seated position using an electronic sphygmomanometer (Omron Dailan, Dalian, Liaoning, China). Accredited site laboratories processed participants' fasting blood samples. These laboratories participated in the External Quality Assurance program of Randox International Quality Assessment Scheme. Fasting plasma glucose

(FPG), HbA1c, triglycerides, total cholesterol, low-density lipoprotein (LDL) cholesterol, and high-density lipoprotein (HDL) cholesterol were analysed using standardized laboratory procedures.²³

Glycemic status was defined according to four categories: pre-diabetes if FPG was ≥ 5.5 mmol/L but < 6.9 mmol/L or HbA1c was $\geq 5.7\%$ but $< 6.5\%$; undiagnosed diabetes if FPG was ≥ 6.9 mmol/L, HbA1c was $\geq 6.5\%$, and the participant responded, “No,” to the question, “Have you ever been told by a doctor that you have diabetes?”; diagnosed diabetes if the participant responded, “Yes,” to the question, “Have you ever been told by a doctor that you have diabetes?”; and no diabetes (referent).

Blood pressure status was also defined according to four categories: pre-hypertension if systolic blood pressure (SBP) was ≥ 120 mmHg but < 140 mmHg and diastolic blood pressure (DBP) was ≥ 80 mmHg but < 90 mmHg; undiagnosed hypertension if SBP ≥ 140 mmHg or DBP ≥ 90 mmHg and the participant responded, “No,” to the question, “Have you ever been told by a doctor that you have hypertension?”; diagnosed hypertension if the participant responded, “Yes,” to the question, “Have you ever been told by a doctor that you have hypertension?”; and no hypertension (referent).

Self-reported history of CVD (heart disease or stroke) was assessed via questionnaire.

Statistical analysis

The association of each dietary pattern with demographic and lifestyle variables were examined across quartiles of each component using means and standard deviations for continuous variables or percent (number) for categorical variables. To improve the clarity with which results are presented, only quartiles 1 and 4 were included in the tables. Bivariate relationships were evaluated using chi-square tests for categorical variables and a nonparametric trend test by the quartile of each dietary pattern (the “nptrend” command in Stata), an extension of the Wilcoxon rank-sum test for trends across ordered groups.²⁹

We used multinomial logistic regression to estimate the odds ratios (OR) and 95% confidence intervals (CI) for the association of dietary pattern quartiles with glycaemic status and blood pressure status (both dependent variables had four categories, as defined above). Binary logistic regression was used to estimate the ORs (95% CIs) for the association of dietary pattern quartiles with obesity and history of CVD. All models were adjusted for age, gender, city (Chennai, Delhi, or Karachi), education (up to primary school, high school to secondary, or postgraduate degree or higher), occupation (not working, semiskilled/unskilled, trained/skilled, or white collar), sedentary time (sitting for more than 4 hours/day), tobacco use (current daily or non-daily users), alcohol use (regular or occasional user in the past 6 months), family history of hypertension (yes, no, or don't know), family history of diabetes (yes, no, or don't know), family history of stroke (yes, no, or don't know), and family history of heart disease (yes, no, or don't know). To assist in interpreting results, in addition to reporting ORs, we also report adjusted prevalence estimates (e.g. marginal effects).³⁰ $p < 0.05$ was considered statistically significant.

RESULTS

Dietary patterns

Six patterns were identified with eigen values > 1 and three components were retained based on evaluation of the scree plot (Supplemental figure 1). Together they explained 29.7% of the total variance in the food groups. Food groups with factor loadings ≥ 0.25 (Table 1) were considered informative for describing that pattern and the three components were labeled as: Prudent, Indian, and Non-Vegetarian. The Prudent Pattern was characterized by more frequent intakes of fruits, green leafy vegetables, other raw vegetables, and nuts. The Indian Pattern was characterized by more frequent intakes of refined grains (including white rice), cooked vegetables, fish, and coffee, and less frequent intakes of whole grains (including whole wheat flour based chapattis). The Non-Vegetarian Pattern was characterized by more frequent intakes of meat, organ meats, poultry, eggs, and fish.

Participants in the highest quartile of the Prudent Pattern were more likely to be men, live in Delhi as compared to Chennai and Karachi, have a post-graduate degree or higher, have a trained/skilled or white collar occupation, a monthly household income $> 10,000$ INR, and have a family history of cardio-metabolic diseases (Table 2). Participants in the highest quartile of the Indian Pattern were more likely to live in Chennai, consume alcohol, sit for more than 4 hours per day and have a family history of diabetes, and less likely to have a family history of hypertension, stroke or heart disease compared to participants in the lowest quartile. Participants in the highest quartile of the Non-Vegetarian Pattern were more likely to live in Chennai, have semi-skilled/unskilled or trained/skilled occupations, and use tobacco and alcohol compared to participants in the lowest quartile. Participants in the highest quartile of the Dietary Diversity Score were less likely to have a monthly household income $< 10,000$ INR, consume alcohol, and have a family history of cardio-metabolic diseases compared to participants in the lowest quartile.

Associations of dietary patterns with glycemic status and blood pressure status

Participants in the highest quartile of the Prudent Pattern were less likely to have diagnosed diabetes compared to those in the lowest quartile (adjusted OR [95% CI], 0.42 [0.30–0.57]; p -trend < 0.01 ; adjusted prevalence [95% CI] 4.7% [3.8–5.6] versus 10.3% [8.5–12.0], respectively) (Figure 1a and Table 3). No association was observed with pre-diabetes or undiagnosed diabetes for the Prudent Pattern after adjustment for confounders (Figure 1b and 1c). Similarly, participants in the highest quartile of the Prudent Pattern were less likely to have diagnosed hypertension compared to those in the lowest quartile (adjusted OR [95% CI], 0.69 [0.51–0.91]; p -trend=0.06; adjusted prevalence [95% CI] 7.5% [6.3–8.8] versus 10.4% [8.8–12.0], respectively), but no association was seen for pre-hypertension or undiagnosed hypertension (Figure 1d, 1e, 1f).

Participants in the highest versus lowest quartile of the Indian Pattern were less likely to have diagnosed diabetes (adjusted OR [95% CI], 0.51 [0.32–0.80]; p -trend < 0.01 ; adjusted prevalence [95% CI] 4.8% [3.7–5.9] versus 8.7% [6.7–10.6], respectively) (Figure 1a) and diagnosed hypertension (adjusted OR [95% CI], 0.55 [0.37–0.83];

Table 1. Factor loadings of food groups included in principal component analysis (PCA).

Food groups	PCA-derived Pattern		
	Prudent	Indian	Non-Vegetarian
Meat			0.40
Poultry			0.44
Organ meat			0.35
Fish		0.26	0.33
Shellfish			0.33
Egg			0.33
Milk			
Desert	0.29		
Deep fry western			
Deep fry traditional			
Western deserts			
Milk based deserts			
Cold beverages			
Fruit1	0.30		
Fruit2	0.35		
Fruitjuice	0.31		
Nuts	0.28		
Leafy green vegetables	0.27		
Other raw vegetables	0.34		
Legumes			
Pickle			
Cooked vegetables		0.46	
Refined grains		0.49	
Whole grains		-0.45	
Tea			
Coffee		0.28	

p -trend=0.01; adjusted prevalence [95% CI] 7.0% [5.4–8.5] versus 10.6% [8.6–12.5], respectively) (Figure 1d), but no significant associations were observed for pre-disease or undiagnosed disease (Figure 1b, 1c, 1e, 1f). The Non-Vegetarian Pattern was only associated with diagnosed diabetes (adjusted OR [95% CI], 0.54 [0.39–0.73]; p -trend<0.01; adjusted prevalence [95% CI] 4.7% [3.7–5.6] versus 8.2% [6.8–9.5] in the highest versus lowest quartile, respectively) (Figure 1a), not diagnosed hypertension (Figure 1d).

For the Dietary Diversity Score, participants in the highest versus lowest quartile were less likely to have diagnosed diabetes (adjusted OR [95% CI], 0.46 [0.33–0.64]; p -trend<0.01; adjusted prevalence [95% CI] 4.1% [3.0–5.2] versus 8.2% [7.1–9.3], respectively) (Figure 1a), diagnosed hypertension (adjusted OR [95% CI], 0.57 [0.44–0.76]; p -trend=0.01; adjusted prevalence [95% CI] 6.7% [5.3–8.1] versus 10.3% [9.1–11.5], respectively) (Figure 1d) and undiagnosed hypertension (adjusted OR [95% CI], 0.68 [0.54–0.87]; p -trend<0.04; adjusted prevalence [95% CI] 14.2% [12.0–16.4] versus 18.5% [16.9–20.1], respectively) (Figure 1e).

Associations of dietary patterns with history of CVD and overweight

Participants in the highest quartile of the Indian Pattern and Non-Vegetarian Pattern were less likely to have a history of CVD compared to those in the lowest quartile: adjusted OR (95% CI), 0.49 (0.25–0.96); p -trend <0.01; adjusted prevalence (95% CI) 1.5% (0.8–2.1) versus 2.9% (2.0–3.8), respectively, for the Indian Pattern, and adjusted OR (95% CI), 0.40 (0.26–0.61); p -trend <0.01; adjusted prevalence (95% CI) 1.5% (1.1–2.0) versus 3.6% (2.8–4.4), respectively, for the Non-Vegetarian Pattern (Figure 2a, 2b, 2c). The Prudent Pattern and the Dietary Diversity Score

were not associated with history of CVD. Across all four dietary patterns, there were no associations with overweight.

DISCUSSION

Three empirically derived dietary patterns were identified using PCA in this sample of adults living in urban areas of South Asia: a Prudent Pattern, an Indian Pattern, and a Non-Vegetarian Pattern. Adults following the Prudent Pattern and Indian Pattern were less likely to have diagnosed diabetes and hypertension, but no significant associations were observed for pre-disease states or undiagnosed disease. Adults following the Prudent Pattern in our sample were less likely to have diagnosed diabetes and hypertension. A plausible interpretation of these findings is that adults in South Asia are changing their diets after chronic disease diagnoses, not necessarily that these patterns are protective.

A study reported by Ganguli et al,³¹ conducted among women in West Bengal, identified three patterns using factor analysis, one of which was the Vegetables, Fruit and Pulses Pattern (characterized by higher intakes of dark yellow and green leafy vegetables, sweets, fruits, pulses, nuts, poultry and eggs, and lower intake of mustard oil), which was similar to the Prudent Pattern we identified with the exception that poultry and eggs also loaded heavily on their pattern. They reported consistent results as CARRS participants with decreased risk of diabetes with increased tertiles of prudent pattern as well as biomarkers of CVD risk (serum total cholesterol, LDL cholesterol, and non HDL cholesterol concentrations). Similarly, another representative survey from Chennai,³² the CURES study reported similar food consumption pattern (low fruits and vegetables with high refined cereals- mainly white rice) such as

Table 2. Characteristics of participants (n=16,287) by quartiles of principal component analysis (PCA)-derived dietary patterns and dietary diversity score

	PCA-derived Patterns									A priori Pattern		
	Prudent			Indian			Non-Vegetarian			Dietary Diversity		
	Q1 (n=4072)	Q4 (n=4071)	p value	Q1 (n=4072)	Q4 (n=4071)	p value	Q1 (n=4072)	Q4 (n=4071)	p value	Q1 (n=4072)	Q4 (n=4071)	p value
Age mean(SD)	42.8 (13.1)	42.7 (13.6)	0.002	42.5 (13.8)	41.3 (12.5)	<0.001	46.9 (13.7)	38.9 (12.2)	<0.001	44.1 (13.5)	38.1(12.4)	<0.001
Men	1632 (40.1)	2286 (56.2)	<0.001	1854 (45.5)	1847 (45.4)	<0.001	1745 (42.9)	2247 (55.2)	<0.001	2604(44.0)	1228 (55.6)	<0.001
Education												
Up to primary schooling	1272 (31.2)	457(11.2)	<0.001	1203 (29.5)	713 (17.5)	<0.001	911(22.4)	747 (18.4)	<0.001	1734 (29.3)	307 (13.2)	<0.001
High school to secondary	2524 (61.9)	2276 (55.9)		2216 (54.4)	2877 (70.8)		2155 (52.9)	2659 (65.3)		3581 (60.5)	1415 (64.1)	
Graduation and above	276 (6.8)	1338 (32.9)		653 (16)	481 (11.8)		1006 (24.7)	665 (16.3)		602 (10.2)	487 (22.1)	
Occupation												
Not working	2384 (58.6)	1867 (45.9)	<0.001	2423 (59.5)	2048 (50.3)	<0.001	2430 (59.7)	1829 (44.9)	<0.001	3413 (57.7)	992 (44.9)	<0.001
Semiskilled/Unskilled	1039 (25.5)	629(15.5)		724 (17.8)	1041 (25.6)		550 (13.5)	1057 (25.9)		1373 (23.2)	474 (21.5)	
Trained/Skilled	603 (14.8)	1261 (30.9)		795 (19.5)	924 (22.7)		886 (21.8)	1047 (25.7)		1013 (17.1)	634 (28.7)	
White collar	46 (1.1)	314 (7.7)		130 (3.2)	58 (1.4)		206 (5.1)	138 (3.4)		118 (2)	109 (4.9)	
Monthly household income												
<10,000 INR	3522 (86.9)	1894 (46.9)	<0.001	3059 (75.7)	3288 (81.0)	<0.001	2113 (52.3)	3131 (77.4)	<0.001	4643 (79.0)	1475(67.1)	<0.001
10,000-20,000 INR	425 (10.5)	942(23.3)		647 (16.0)	584 (14.4)		810(20.0)	650(16.1)		774 (13.2)	403 (18.3)	
>20,000 INR	107(2.6)	1200 (29.7)		334 (8.3)	186(4.6)		1118 (27.7)	264(6.5)		461 (7.8)	320 (14.6)	
City												
Chennai	2735 (67.2)	792(19.5)	<0.001	27(0.66)	4003 (98.3)	<0.001	597(14.7)	2333 (57.3)	<0.001	2963 (50.1)	842 (38.1)	<0.001
Delhi	312 (7.7)	2677 (65.8)		870 (21.4)	57(1.4)		3082 (75.7)	515(12.7)		1632 (27.6)	752 (34.3)	
Karachi	1025 (25.2)	602(14.8)		3175 (77.9)	11(0.3)		393 (9.7)	1223 (30.0)		1322 (22.3)	610 (27.6)	
Tobacco consumption	952 (23.4)	841 (20.7)	<0.001	1035 (25.4)	816 (21.8)	<0.001	707 (17.4)	1198 (29.4)	<0.001	1442 (24.4)	548(24.8)	<0.001
Alcohol consumption	600 (14.7)	649 (15.9)	<0.001	140 (3.7)	839 (20.6)	<0.001	149 (3.7)	839 (20.6)	<0.001	794 (13.4)	390 (17.7)	<0.001
Family history of diabetes	1091 (26.8)	1122 (27.6)	<0.001	966 (23.7)	1397 (34.3)	<0.001	834 (20.5)	1271 (31.3)	<0.001	1379 (23.3)	655 (29.7)	<0.001
Family history of hypertension	746 (18.3)	957 (23.5)	<0.001	1084 (26.6)	785 (19.3)	<0.001	714 (17.5)	1013 (24.9)	<0.001	1015 (17.2)	513 (23.2)	<0.001
Family history of stroke	75 (1.8)	189 (4.6)	<0.001	223 (5.5)	45 (1.1)	<0.001	175 (4.3)	145 (3.6)	<0.001	146 (2.5)	93 (4.2)	<0.001
Family history of heart disease	283 (6.9)	547 (13.4)	<0.001	613 (15.1)	244 (6.0)	<0.001	460 (11.3)	442 (10.9)	<0.001	462 (7.8)	247 (11.2)	<0.001
Sedentary time (sitting for more than 4 hours/day)	3057 (75.3)	2932 (72.2)	<0.001	2545 (62.9)	3424 (84.2)	<0.001	3041 (74.7)	3090 (76.1)	<0.001	4185 (70.9)	1624 (73.8)	<0.001

Dietary diversity score was calculated based on food group consumption at least once per week.

Table 3. Odds of diabetes, hypertension, obesity and history of cardiovascular disease (CVD) associated with quartiles of principal component analysis-derived dietary patterns and dietary diversity scores.

		Unadjusted odds ratio (95% CI)				<i>p</i> for trend	Adjusted odds ratio (95% CI)				<i>p</i> for trend
		Quartile 1	Quartile 2	Quartile 3	Quartile 4		Quartile 1	Quartile 2	Quartile 3	Quartile 4	
Prudent Pattern	Diagnosed diabetes	Ref	0.57*** (0.46, 0.71)	0.59*** (0.47, 0.74)	0.72* (0.55, 0.94)	0.09	Ref	0.64** (0.49, 0.83)	0.52*** (0.40, 0.68)	0.40*** (0.29, 0.55)	<0.01
	Undiagnosed diabetes	Ref	0.83 (0.69, 1.00)	1.01 (0.83, 1.24)	1.66*** (1.34, 2.06)	<0.01	Ref	0.80 (0.62, 1.02)	0.94 (0.73, 1.20)	0.89 (0.68, 1.17)	0.39
	Pre-diabetes	Ref	0.88 (0.77, 1.02)	0.99 (0.86, 1.15)	1.32*** (1.13, 1.55)	<0.01	Ref	0.90 (0.76, 1.06)	0.88 (0.74, 1.05)	0.90 (0.74, 1.10)	0.96
	Diagnosed hypertension	Ref	0.95 (0.77, 1.18)	0.96 (0.80, 1.16)	1.18 (0.94, 1.49)	0.03	Ref	0.93 (0.75, 1.16)	0.81 (0.64, 1.03)	0.69** (0.52, 0.91)	0.06
	Undiagnosed hypertension	Ref	1.02 (0.85, 1.23)	0.96 (0.82, 1.12)	1.40*** (1.19, 1.67)	<0.01	Ref	1.01 (0.82, 1.24)	0.86 (0.70, 1.06)	0.89 (0.70, 1.13)	0.29
	Pre-hypertension	Ref	1.03 (0.89, 1.20)	1.07 (0.95, 1.23)	1.49*** (1.31, 1.70)	<0.01	Ref	0.99 (0.84, 1.18)	0.93 (0.78, 1.11)	1.01 (0.83, 1.23)	0.56
	Obesity	Ref	0.91 (0.76, 1.09)	1.02 (0.87, 1.20)	1.19 (0.99, 1.45)	<0.01	Ref	1.07 (0.90, 1.28)	1.07 (0.89, 1.28)	1.07 (0.87, 1.31)	0.99
	History of CVD	Ref	0.84 (0.63, 1.14)	0.79 (0.58, 1.08)	0.81 (0.60, 1.09)	0.90	Ref	0.79 (0.54, 1.14)	0.62* (0.39, 0.99)	0.57* (0.35, 0.94)	0.29
Indian Pattern	Diagnosed diabetes	Ref	1.89*** (1.47, 2.44)	1.76*** (1.28, 2.43)	1.31 (0.92, 1.87)	<0.01	Ref	1.05 (0.77, 1.41)	0.75 (0.51, 1.10)	0.51** (0.32, 0.80)	<0.01
	Undiagnosed diabetes	Ref	2.43*** (2.05, 2.90)	1.47** (1.16, 1.86)	1.06 (0.81, 1.40)	<0.01	Ref	1.21 (0.93, 1.58)	1.03 (0.74, 1.44)	0.98 (0.64, 1.48)	0.47
	Pre-diabetes	Ref	2.30*** (1.98, 2.68)	1.64*** (1.37, 1.97)	1.31** (1.09, 1.59)	<0.01	Ref	1.14 (0.93, 1.39)	0.90 (0.70, 1.17)	0.93 (0.69, 1.26)	0.11
	Diagnosed hypertension	Ref	1.02 (0.84, 1.25)	0.76* (0.60, 0.98)	0.50*** (0.37, 0.68)	<0.01	Ref	0.90 (0.71, 1.17)	0.82 (0.59, 1.12)	0.55** (0.37, 0.83)	0.01
	Undiagnosed hypertension	Ref	1.53*** (1.27, 1.87)	1.14 (0.89, 1.48)	0.92 (0.68, 1.27)	<0.01	Ref	0.85 (0.67, 1.08)	0.87 (0.65, 1.16)	0.73 (0.51, 1.04)	0.33
	Pre-hypertension	Ref	1.29*** (1.11, 1.51)	1.14 (0.96, 1.37)	1.00 (0.81, 1.25)	<0.01	Ref	0.86 (0.71, 1.04)	0.95 (0.74, 1.21)	0.83 (0.62, 1.11)	0.26
	Obesity	Ref	0.89 (0.76, 1.04)	0.78* (0.63, 0.98)	0.74** (0.60, 0.92)	0.11	Ref	0.97 (0.80, 1.16)	1.07 (0.84, 1.35)	1.02 (0.76, 1.37)	0.62
	History of CVD	Ref	0.90 (0.71, 1.15)	0.85 (0.64, 1.15)	0.38*** (0.28, 0.54)	0.01	Ref	1.21 (0.86, 1.70)	1.15 (0.72, 1.85)	0.49* (0.25, 0.96)	<0.01

Models for diabetes and hypertension were adjusted for site, age, gender, education, occupation, income, tobacco consumption, alcohol consumption, sedentary time, BMI, waist circumference, family history of hypertension, family history of diabetes, family history of stroke, and family history of heart disease.

Models for obesity were adjusted for site, age, gender, education, occupation, income, tobacco consumption, alcohol consumption, sedentary time, family history of hypertension, family history of diabetes, family history of stroke, and family history of heart disease.

Models for history of CVD were adjusted for site, age, gender, education, occupation, income, tobacco consumption, alcohol consumption, sedentary time, BMI, waist circumference, family history of hypertension, family history of diabetes, family history of stroke, and family history of heart disease.

Table 3. Odds of diabetes, hypertension, obesity and history of cardiovascular disease (CVD) associated with quartiles of principal component analysis-derived dietary patterns and dietary diversity scores (cont.).

	Unadjusted odds ratio (95% CI)					Adjusted odds ratio (95% CI)]					
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	<i>p</i> for trend	Quartile 1	Quartile 2	Quartile 3	Quartile 4	<i>p</i> for trend	
Non vegetarian Pattern	Diagnosed Diabetes	Ref	0.59*** (0.47, 0.74)	0.41*** (0.33, 0.53)	0.28*** (0.22, 0.37)	<0.01	Ref	0.94 (0.71, 1.23)	0.91 (0.68, 1.22)	0.54*** (0.39, 0.73)	<0.01
	Undiagnosed Diabetes	Ref	0.41*** (0.34, 0.51)	0.34*** (0.28, 0.42)	0.27*** (0.22, 0.35)	<0.01	Ref	0.85 (0.66, 1.07)	0.99 (0.76, 1.30)	0.87 (0.67, 1.14)	0.33
	Pre-diabetes	Ref	0.57*** (0.50, 0.66)	0.52*** (0.44, 0.61)	0.43*** (0.38, 0.51)	<0.01	Ref	0.97 (0.81, 1.17)	1.04 (0.85, 1.26)	0.99 (0.81, 1.21)	0.74
	Diagnosed Hypertension	Ref	0.67*** (0.56, 0.82)	0.48*** (0.39, 0.59)	0.36*** (0.29, 0.46)	<0.01	Ref	1.08 (0.85, 1.36)	1.05 (0.82, 1.36)	0.78 (0.59, 1.02)	0.01
	Undiagnosed Hypertension	Ref	0.74*** (0.63, 0.89)	0.59*** (0.49, 0.71)	0.60*** (0.51, 0.72)	<0.01	Ref	1.23* (1.00, 1.51)	1.20 (0.96, 1.50)	1.11 (0.88, 1.40)	0.58
	Pre-hypertension	Ref	0.79** (0.69, 0.91)	0.73*** (0.65, 0.84)	0.77*** (0.68, 0.88)	0.55	Ref	1.23* (1.03, 1.47)	1.24* (1.02, 1.49)	1.21 (1.00, 1.46)	0.95
	Obesity	Ref	0.95 (0.80, 1.15)	0.72** (0.59, 0.88)	0.88 (0.72, 1.09)	0.02	Ref	1.11 (0.93, 1.33)	1.13 (0.93, 1.36)	1.14 (0.94, 1.39)	0.96
	History of CVD	Ref	0.75* (0.59, 0.97)	0.63** (0.46, 0.87)	0.32*** (0.24, 0.43)	0.001	Ref	0.79 (0.56, 1.12)	0.80 (0.51, 1.26)	0.40*** (0.26, 0.61)	<0.01
Dietary Diversity Score	Diagnosed Diabetes	Ref	0.88 (0.74, 1.06)	0.58*** (0.48, 0.72)	0.29*** (0.22, 0.40)	<0.001	Ref	0.92 (0.73, 1.16)	0.65*** (0.51, 0.83)	0.46*** (0.33, 0.64)	<0.01
	Undiagnosed Diabetes	Ref	0.99 (0.84, 1.19)	0.91 (0.77, 1.08)	0.66*** (0.53, 0.83)	0.01	Ref	1.01 (0.81, 1.24)	0.87 (0.70, 1.08)	0.84 (0.65, 1.09)	0.30
	Pre-diabetes	Ref	0.92 (0.83, 1.04)	0.82** (0.73, 0.93)	0.73*** (0.63, 0.85)	0.14	Ref	0.97 (0.83, 1.14)	0.84* (0.72, 0.98)	0.97 (0.81, 1.18)	0.12
	Diagnosed Hypertension	Ref	0.95 (0.81, 1.12)	0.81** (0.69, 0.95)	0.42*** (0.34, 0.52)	<0.001	Ref	0.94 (0.77, 1.15)	0.75** (0.61, 0.92)	0.57*** (0.44, 0.76)	<0.01
	Undiagnosed Hypertension	Ref	0.93 (0.81, 1.07)	0.96 (0.83, 1.12)	0.62*** (0.52, 0.75)	<0.001	Ref	0.91 (0.76, 1.09)	0.91 (0.76, 1.09)	0.68*** (0.54, 0.87)	0.04
	Pre-hypertension	Ref	1.07 (0.95, 1.20)	1.09 (0.97, 1.23)	0.90 (0.79, 1.05)	0.19	Ref	0.99 (0.85, 1.15)	0.96 (0.82, 1.12)	0.98 (0.81, 1.18)	0.94
	Obesity	Ref	0.96 (0.83, 1.13)	1.04 (0.91, 1.21)	0.94 (0.80, 1.11)	0.93	Ref	1.08 (0.93, 1.26)	1.12 (0.96, 1.30)	1.07 (0.87, 1.32)	0.89
	History of CVD	Ref	0.78 (0.61, 1.01)	0.58*** (0.44, 0.76)	0.41*** (0.25, 0.67)	0.01	Ref	0.82 (0.60, 1.12)	0.57*** (0.26, 0.61)	0.57 (0.30, 1.09)	0.13

Models for diabetes and hypertension were adjusted for site, age, gender, education, occupation, income, tobacco consumption, alcohol consumption, sedentary time, BMI, waist circumference, family history of hypertension, family history of diabetes, family history of stroke, and family history of heart disease.

Models for obesity were adjusted for site, age, gender, education, occupation, income, tobacco consumption, alcohol consumption, sedentary time, family history of hypertension, family history of diabetes, family history of stroke, and family history of heart disease.

Models for history of CVD were adjusted for site, age, gender, education, occupation, income, tobacco consumption, alcohol consumption, sedentary time, BMI, waist circumference, family history of hypertension, family history of diabetes, family history of stroke, and family history of heart disease.

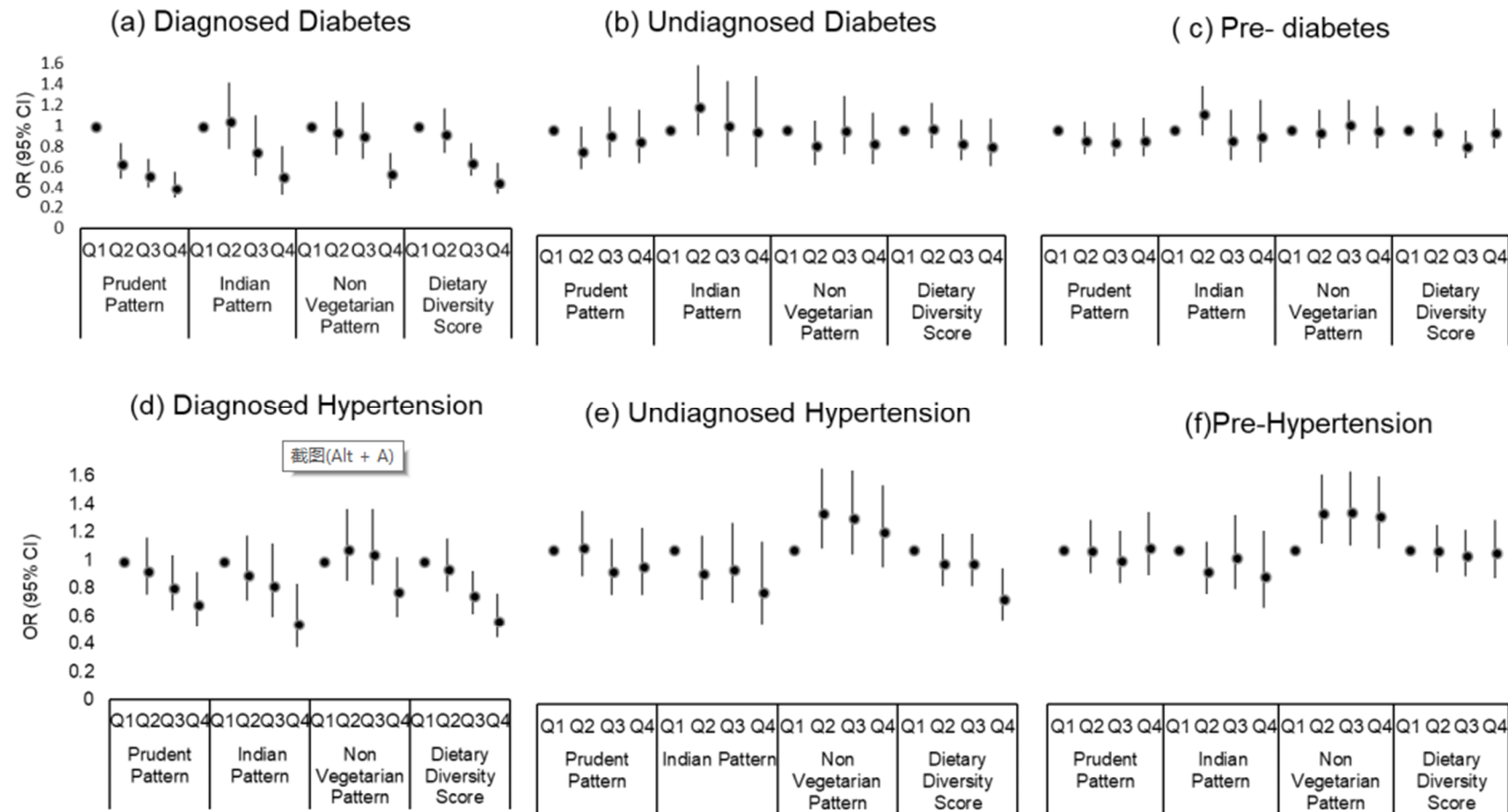


Figure 1. Odds of (a) diagnosed diabetes, (b) undiagnosed diabetes, (c) pre-diabetes, (d) diagnosed hypertension, (e) undiagnosed hypertension, and (f) pre-hypertension, according to quartiles of principal component analysis-derived dietary patterns and dietary diversity scores estimated using multivariable multinomial logistic regression. Adjusted for site, age, gender, education attainment, occupation, monthly household income, tobacco use, alcohol consumption, sedentary time, body mass index, waist circumference, family history of hypertension, family history of diabetes, family history of stroke, and family history of heart disease. CI: confidence interval; OR: odds ratio.

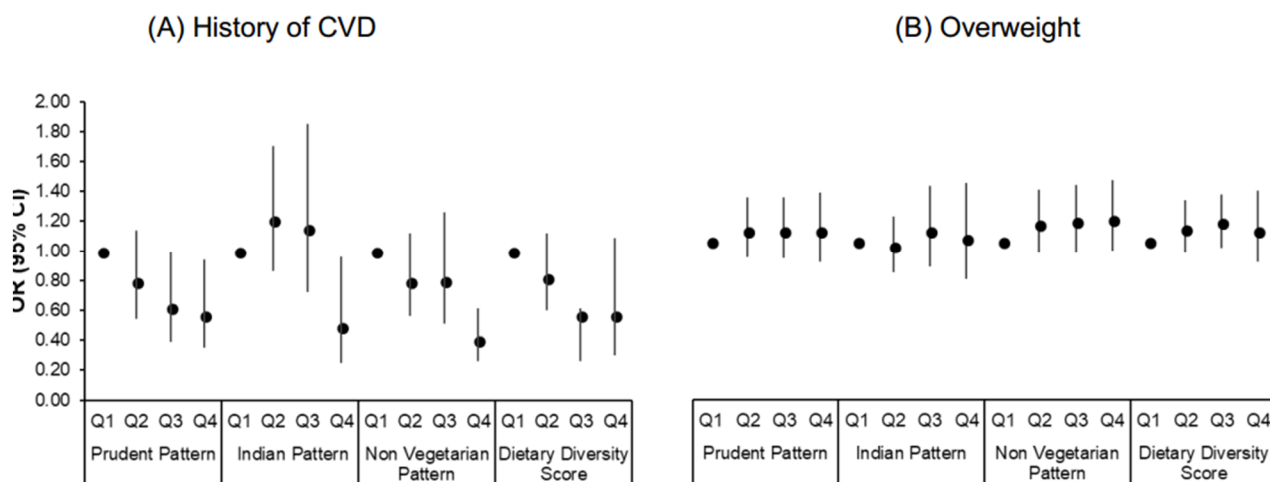


Figure 2. Odds of (a) history of cardiovascular disease (CVD) and (b) overweight defined as body mass index (BMI) ≥ 25 kg/m² according to quartile of principal component analysis-derived dietary patterns and dietary diversity scores estimated using multivariable binary logistic regression. Model in (a) is adjusted for site, age, gender, education attainment, occupation, monthly household income, tobacco use, alcohol consumption, sedentary time, BMI, waist circumference, family history of hypertension, family history of diabetes, family history of stroke, and family history of heart disease. Model (b) is adjusted for site, age, gender, education attainment, occupation, monthly household income, tobacco use, alcohol consumption, sedentary time, family history of hypertension, family history of diabetes, family history of stroke, and family history of heart disease. BMI: body mass index; CI: confidence interval; CVD: cardiovascular disease; OR: odds ratio.

the Indian pattern reported here. They too observed positive association between refined grain intake with risk of type 2 diabetes [OR (95% CI), 5.31 (2.98–9.); *p*-trend < 0.001].³³

Participants in the highest quartile of the Non-Vegetarian Pattern were less likely to have diagnosed diabetes and a history of CVD compared to those in the lowest quartile. There was no association observed with overweight. This is not consistent with the findings of the Indian Migration Study,³⁴ which is a cross-sectional study conducted at four factory locations across India: Lucknow, Nagpur, Hyderabad, and Bangalore. In that study, three dietary patterns were identified using PCA based on a semi-quantitative FFQ: Cereal Pattern (savory foods containing cooked grains, rice/rice based dishes, snacks, condiments, soups, and nuts); Fruit-Vegetables-Sweets-Snacks Pattern (Western cereals, vegetables, fruit, fruit juices, cooked milk products, snacks, sugars, and sweets); and Animal-Food Pattern (red meat, poultry, fish/seafood, and eggs). They found positive, graded associations across quintiles of the Animal-Food Pattern with both obesity (BMI ≥ 25 kg/m²) and central obesity (waist circumference ≥ 94 cm for men and ≥ 80 cm for women) that were not explained by confounding factors. However, this association was attenuated after adjusting for calories from protein (obtained from three 24-hour dietary recalls) in the fully adjusted model. Participants from CARRS reported a relatively low animal food intake compared to this study and thus, we did not see a strong association.

In another study based in three cities in India (Delhi, Mumbai, and Trivandrum), the authors identified two dietary patterns using factor analysis for each region.³⁵ In Delhi, the Fruit and Dairy Pattern (including fruit, fruit juice, cheese, yogurt and other types of dairy) was positively associated with both abdominal adiposity (waist circumference to hip circumference ratio greater than or equal

to 0.90 in men and 0.80 in women) and hypertension (positive medical history with valid treatment for high blood pressure or SBP ≥ 140 mmHg or DBP ≥ 90 mmHg), but not associated with diabetes (self-reported and/or impaired fasting glucose ≥ 6.9 mmol/L and/or medication use) or dyslipidaemia (HDL cholesterol < 1.0 mmol/L in men or 1.2 mmol/L in women and/or triglyceride levels > 2.2 mmol/L and/or total cholesterol to HDL cholesterol ratio ≥ 5). In Trivandrum, the Pulses-Rice Pattern was inversely associated with diabetes and/or prediabetes (impaired fasting glucose ≥ 5.5 mmol/L). The Sweets-Snacks Pattern was positively associated with abdominal adiposity and prediabetes but not associated with diabetes or hypertension. In Mumbai, the Fruit and Vegetables Pattern was inversely associated with hypertension, while the Snack-Meat Pattern was positively associated with abdominal adiposity. After adjustment for key demographic and lifestyle confounders, diets across all regions characterized by dairy, fried snacks, and sweets appeared to be positively associated with abdominal adiposity while dietary patterns in Trivandrum and Mumbai, characterized by intake of vegetables and pulses, were inversely associated with diabetes and hypertension. This is similar to what we observed in CARRS with respect to diagnosed diabetes and hypertension.

The Control of Blood Pressure and Risk Attenuation (COBRA) study³⁶ in Karachi identified three patterns: Fat and Sweet Pattern, Fruit and Vegetable Pattern, and Seafood and Yogurt Pattern. The Fruit and Vegetable Pattern was similar to the Prudent Pattern we identified in CARRS, but showed no significant association with hypertension in the COBRA study.

Differences between previous studies in South Asia and our study may be due to differences in the exact food groups that loaded onto the dietary patterns – and to what degree they loaded; differences in the underlying sample

populations and thus distribution of the exposures, outcomes, and confounding effects; and/or residual confounding, among other factors.

Interestingly, we found that a diverse diet, based on an a priori dietary diversity score (as opposed to a data-driven approach such as PCA), was associated with lower odds of both undiagnosed and diagnosed hypertension, suggesting that dietary diversity is an etiologically protective factor that could be important for preventing CVD. The findings of Kant et al also support the role of variety in diet as a possible approach for preventing CVD.³⁷ They examined the relation of a measure of overall diet quality with mortality from CVD, cancer, and non-CVD, non-cancer (other) causes using data from NHANES. They scored dietary diversity using five major food groups: dairy, meat, grain, fruit, and vegetables consumed daily from 24-hour dietary recalls. Their results suggested an increased age-adjusted risk of CVD and cancer mortality associated with diets characterized by omission of several major food groups. Further investigation of this observation is clearly warranted.

The main strength of the study is its relatively large sample size of a representative population of Delhi, Chennai and Karachi and newly diagnosed diseased subjects adding to the paucity of information available in this population. It does have several limitations. Firstly, diet was assessed retrospectively using an interviewer administered FFQ, which has modest measurement error.^{38,39} However, for studying the role of diet in the CARRS study, measurement of past intake is of greater relevance than existing diet as we are interested in etiological exposure-disease relationships. Moreover, our FFQ only assessed intake of 26 food items, which may partially explain the fact that the dietary patterns explained only 29.7% of the total variance. Although other studies from India also report similar variance estimates: 28.6% in the Indian Migration Study³⁴ and 27% in the west Bengal study.³¹ Secondly, even though we adjusted for major confounders, residual and unmeasured confounding may impact results. For example, we do not have detailed information on moderate physical activity from one of the sites and therefore were limited to adjusting for sedentary time.^{40,41} Third, the FPQ did not include portion size estimates and therefore we could not evaluate whether certain participants had outlying energy intake data. Finally, this was a cross-sectional analysis, thus we are not able to infer causality and estimated associations are likely subject to reverse causality. We addressed this by estimating associations separately for undiagnosed and diagnosed diabetes as those who were diagnosed may change their dietary intake. Results reported here suggest that this may indeed be the case in this sample population, and therefore further, prospective research is warranted.

To summarize, in the present South Asian adult population, those following a prudent or Indian dietary pattern were less likely to have diagnosed diabetes and hypertension, with no significant associations for pre-disease states or undiagnosed disease. This could be due to reverse causality: adults in urban South Asia are changing their diets after a disease diagnosis. On the other hand, a diverse diet was associated with lower odds of both undiagnosed and diagnosed hypertension, suggesting a potentially etiologically protective factor that could be important for primary

prevention. This could be taken into consideration when nutrition education programmes are planned, although further investigation is warranted.

ACKNOWLEDGEMENTS

All authors were involved in the conception and development of the research plan (study question and analysis). KS conducted the statistical analysis. DK and LMJ wrote the paper. All other authors contributed to editing and revising the paper. DK has primary responsibility for final content. All authors read and approved the final manuscript.

AUTHOR DISCLOSURES

The authors have no conflicts of interest to declare.

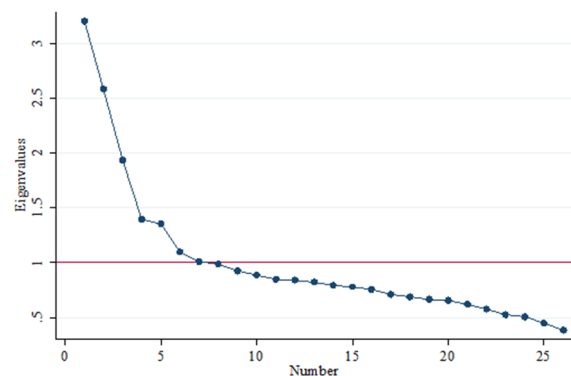
Funding disclosure

The CARRS (Centre for cArdiometabolic Risk Reduction in South-Asia) cohort was funded by the National Heart, Lung, and Blood Institute at the National Institutes of Health (HHSN2682009900026C) and the Oxford Health Alliance Vision 2020 of the UnitedHealth Group (Minneapolis, MN, USA). Additional support was provided by the Fogarty International Center and the Eunice Kennedy Shriver National Institute of Child Health & Human Development at the National Institutes of Health (1 D43 HD065249), and the Emory Global Health Institute. None of the aforementioned funding sources had a role in the design, analysis, or writing of this article.

REFERENCES

1. Dietary Guidelines for Americans 8th edition 2016. Assessed on February 2, 2017; Available from: <http://health.gov/dietaryguidelines/2015/guidelines/>.
2. Dietary Guidelines for the Brazilian Population. 2017 Accessed on February 2, 2017; Available from: http://bvsms.saude.gov.br/bvs/publicoes/dietary_guidelines_brazilian_population/.
3. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol.* 2002;13:3-9.
4. Hu FB, Rimm EB, Stampfer MJ, Ascherio A, Spiegelman D, Willett WC. Prospective study of major dietary patterns and risk of coronary heart disease in men. *Am J Clin Nutr.* 2000; 72:912-21.
5. Osler M, Heitmann BL, Gerdes LU, Jorgensen LM, Schroll M. Dietary patterns and mortality in Danish men and women: a prospective observational study. *Br J Nutr.* 2001;85:219-25.
6. Quatromoni PA, Copenhafer DL, Demissie S, D'Agostino RB, O'Horo CE, Nam BH et al. The internal validity of a dietary pattern analysis. *The Framingham Nutrition Studies. J Epidemiol Community Health.* 2002;56:381-8.
7. Terry P, Hu FB, Hansen H, Wolk A. Prospective study of major dietary patterns and colorectal cancer risk in women. *Am J Epidemiol.* 2001;154:1143-9.
8. Fung TT, Willett WC, Stampfer MJ, Manson JE, Hu FB. Dietary patterns and the risk of coronary heart disease in women. *Arch Intern Med.* 2001;161:1857-62.
9. Denova-Gutierrez E, Castanon S, Talavera JO, Gallegos-Carrillo K, Flores M, Dosamantes-Carrasco D et al. Dietary patterns are associated with metabolic syndrome in an urban Mexican population. *J Nutr.* 2010;140:1855-63.
10. Esmailzadeh A, Kimiagar M, Mehrabi Y, Azadbakht L, Hu FB, Willett WC. Dietary patterns, insulin resistance, and prevalence of the metabolic syndrome in women. *Am J Clin Nutr.* 2007;85:910-8.
11. Panagiotakos DB, Pitsavos C, Skoumas Y, Stefanadis C. The association between food patterns and the metabolic syndrome using principal components analysis: The ATTICA Study. *J Am Diet Assoc.* 2007;107:979-87; quiz 97.

12. van Dam RM, Rimm EB, Willett WC, Stampfer MJ, Hu FB. Dietary patterns and risk for type 2 diabetes mellitus in U.S. men. *Ann Intern Med.* 2002;136:201-9.
13. Amini M, Esmailzadeh A, Shafaeizadeh S, Behrooz J, Zare M. Relationship between major dietary patterns and metabolic syndrome among individuals with impaired glucose tolerance. *Nutrition.* 2010;26:986-92.
14. Song SJ, Lee JE, Paik HY, Park MS, Song YJ. Dietary patterns based on carbohydrate nutrition are associated with the risk for diabetes and dyslipidemia. *Nutr Res Pract.* 2012;6:349-56.
15. Tucker KL. Dietary patterns, approaches, and multicultural perspective. *Appl Physiol Nutr Metab.* 2010;35:211-8.
16. Kennedy E. Dietary diversity, diet quality, and body weight regulation. *Nutr Rev.* 2004;62:S78-81.
17. McCullough ML, Feskanich D, Stampfer MJ, Giovannucci EL, Rimm EB, Hu FB et al. Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. *Am J Clin Nutr.* 2002;76:1261-71.
18. Raynor HA, Epstein LH. Dietary variety, energy regulation, and obesity. *Psychol Bull.* 2001;127:325-41.
19. Raynor HA, Jeffery RW, Tate DF, Wing RR. Relationship between changes in food group variety, dietary intake, and weight during obesity treatment. *Int J Obes Relat Metab Disord.* 2004;28:813-20.
20. Azadbakht L, Mirmiran P, Azizi F. Dietary diversity score is favorably associated with the metabolic syndrome in Tehranian adults. *Int J Obes (Lond).* 2005;29:1361-7.
21. Wahlqvist ML, Lo CS, Myers KA. Food variety is associated with less macrovascular disease in those with type II diabetes and their healthy controls. *J Am Coll Nutr.* 1989;8:515-23.
22. Miller WL, Crabtree BF, Evans DK. Exploratory study of the relationship between hypertension and diet diversity among Saba Islanders. *Public Health Rep.* 1992;107:426-32.
23. Nair M, Ali MK, Ajay VS, Shivashankar R, Mohan V, Pradeepa R et al. CARRS Surveillance study: design and methods to assess burdens from multiple perspectives. *BMC Public Health.* 2012;12:701-2458-12-701.
24. Rosenberg DE, Bull FC, Marshall AL, Sallis JF, Bauman AE. Assessment of sedentary behavior with the International Physical Activity Questionnaire. *J Phys Act Health.* 2008;5(Suppl 1):S30-44.
25. Iqbal R, Anand S, Ounpuu S, Islam S, Zhang X, Rangarajan S et al. Dietary patterns and the risk of acute myocardial infarction in 52 countries: results of the INTERHEART study. *Circulation.* 2008;118:1929-37.
26. Newby PK, Hu FB, Rimm EB, Smith-Warner SA, Feskanich D, Sampson L et al. Reproducibility and validity of the Diet Quality Index Revised as assessed by use of a food-frequency questionnaire. *Am J Clin Nutr.* 2003;78:941-9.
27. Rockville MW, Inc, editor. NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY III: Body Measurements (Anthropometry) Manual. 1988.
28. Data. WLC-i-P. Accessed on September 2, 2016; Available from: http://apps.who.int/iris/bitstream/10665/42665/1/WHO_TRS_916.pdf.
29. Tonstad S, Butler T, Yan R, Fraser GE. Type of vegetarian diet, body weight, and prevalence of type 2 diabetes. *Diabetes Care.* 2009;32:791-6.
30. DG A. Practical statistics for medical research. New York: Chapman and Hall/CRC press; 1990.
31. Ganguli D, Das N, Saha I, Biswas P, Datta S, Mukhopadhyay B et al. Major dietary patterns and their associations with cardiovascular risk factors among women in West Bengal, India. *Br J Nutr.* 2011;105:1520-9.
32. Radhika G, Sathya RM, Ganesan A, Saroja R, Vijayalakshmi P, Sudha V et al. Dietary profile of urban adult population in South India in the context of chronic disease epidemiology (CURES-68). *Public Health Nutr.* 2011;14:591-8.
33. Mohan V, Deepa R, Velmurugan K, Gokulakrishnan K. Association of small dense LDL with coronary artery disease and diabetes in urban Asian Indians - the Chennai Urban Rural Epidemiology Study (CURES-8). *J Assoc Physicians India.* 2005;53:95-100.
34. Satija A, Hu FB, Bowen L, Bharathi AV, Vaz M, Prabhakaran D et al. Dietary patterns in India and their association with obesity and central obesity. *Public Health Nutr.* 2015;18:3031-41.
35. Daniel CR, Prabhakaran D, Kapur K, Graubard BI, Devasenapathy N, Ramakrishnan L et al. A cross-sectional investigation of regional patterns of diet and cardio-metabolic risk in India. *Nutr J.* 2011;10:12.
36. Safdar NF, Bertone-Johnson ER, Cordeiro L, Jafar TH, Cohen NL. Dietary patterns and their association with hypertension among Pakistani urban adults. *Asia Pac J Clin Nutr.* 2015;24:710-9.
37. Kant AK, Schatzkin A, Ziegler RG. Dietary diversity and subsequent cause-specific mortality in the NHANES I epidemiologic follow-up study. *J Am Coll Nutr.* 1995;14:233-8.
38. Freedman LS, Carroll RJ, Wax Y. Estimating the relation between dietary intake obtained from a food frequency questionnaire and true average intake. *Am J Epidemiol.* 1991;134:310-20.
39. Rosner B, Spiegelman D, Willett WC. Correction of logistic regression relative risk estimates and confidence intervals for random within-person measurement error. *Am J Epidemiol.* 1992;136:1400-13.
40. Crespo CJ, Smit E, Andersen RE, Carter-Pokras O, Ainsworth BE. Race/ethnicity, social class and their relation to physical inactivity during leisure time: results from the Third National Health and Nutrition Examination Survey, 1988-1994. *Am J Prev Med.* 2000;18:46-53.
41. Yates T, Davies MJ, Gray LJ, Webb D, Henson J, Gill JM et al. Levels of physical activity and relationship with markers of diabetes and cardiovascular disease risk in 5474 white European and South Asian adults screened for type 2 diabetes. *Prev Med.* 2010;51:290-4.



Supplemental figure 1. Scree plot of eigenvalues from principal component analysis.

Supplemental table 1. Summary of 26 food items used in principal component analysis (PCA), corresponding 8 items used in the calculation of the dietary diversity score, and comparison to food groups in INTERHEART food frequency questionnaire (FFQ).

FFQ item*	Dietary diversity score food group	INTERHEART food group
Lamb, mutton, goat, veal, rabbit, beef, pork	Non vegetarian food group	Meats
Chicken, turkey, duck, quail, pheasant		
Organ meats (liver, kidney, brain, spleen, heart, and sausages)		
Fresh-water and marine fish, preserved fish such as salted fish, canned fish, dried fish		Fish
Crab, squid, prawns, mollusks, caviar		
Chicken and duck eggs		Eggs
Milk, yogurt, cheese, curd, raita, lassi, milk based drinks	Milk and milk products	Dairy
Milk based desserts (custard, khoya, firni, kheer, milk puddings, rasgullah/rasmalai, ice cream)		
Western style deep fried foods (French fries, potato chips, onion rings, chicken nuggets)	Fats and oils	Fried foods
South Asian style deep fried foods (samosas, papad, pakoras, sev, namakparay, egg rolls, poori, kachori)		
Peanuts, almonds, sunflower seeds, cashews, walnuts		Nuts
Daals, chickpeas, lentils	Pulses	Legumes
Fruits 1 (strawberries, apples, jamuns)	Fruit	Fruit
Fruits 2 (all seasonal fruits except the ones above)		
Fruit juices		
Leafy greens (spinach, mustard greens, turnip greens, asparagus)	Vegetables	Green leafy vegetables
Other raw vegetables (any raw vegetables not included in the preceding categories)		Other raw vegetables
Other cooked vegetables (any cooked vegetables not included in the preceding categories)		Other cooked vegetables
Whole grains (roti made with whole meal flour, brown rusk, whole wheat porridge, whole meal/brown bread)	Grains	Whole grains
Refined grains (boiled rice, fried rice, biryani, pulao, idli, dosa, semolina, sago, pearl barley, pasta, sheermal, taftan, white bread)		Refined grains
Western style desserts (cakes, pies, chocolate, candy, cookies)	Sugars	Desserts/sweet snacks
South Asian style desserts (burfi/ladoo, gulabjamun, halwa, shameia, mohalabeia)		
Carbonated beverages, other soft drinks		
Pickles	Not included in dietary diversity score	Pickled foods
Tea		N/A
Coffee		N/A
N/A	N/A	Soy and other sauces
N/A	N/A	Salty snacks
N/A	N/A	Sugar
N/A	N/A	Tofu

*Used directly in the PCA.