METABOLIC SYNDROME AND RELATED DISORDERS
Volume 8, Number 2, 2010

Pp. 157–164
DOI: 10.1089/met.2009.0062

Prevalence and Correlates of Diabetes in South Asian Indians in the United States: Findings From the Metabolic Syndrome and Atherosclerosis in South Asians Living in America Study and the Multi-Ethnic Study of Atherosclerosis

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Abstract

Background: Individuals from South Asia have high diabetes prevalence despite low body weight. We compared the prevalence of diabetes among South Asian Indians with other U.S. ethnic groups and explored correlates of diabetes.
Methods: This was a cross-sectional study of 150 South Asian Indians (ages 45–79) in California, using similar methods to the Multi-Ethnic Study of Atherosclerosis (MESA). Type 2 diabetes was classified by fasting plasma glucose (FPG) ≥126 mg/dL, 2-h postchallenge glucose ≥200 mg/dL, or use of hypoglycemic medication.
Results: A total of 29% of Asian Indians had diabetes, 37% had prediabetes, and 34% had normal glucose tolerance. After full adjustment for covariates, Indians still had significantly higher odds of diabetes compared to whites and Latinos, but not significantly different from African Americans and Chinese Americans in MESA: Indians [odds ratio (OR), 1.0], whites [OR, 0.29; 95% confidence interval (CI), 0.17–0.49], Latinos (OR, 0.59; CI, 0.34–1.00) African Americans (OR, 0.77; CI 0.45–1.32), Chinese Americans (OR, 0.78, CI, 0.45–1.32). Variables associated with prediabetes or diabetes among Indians included hypertension, fatty liver, visceral adiposity, microalbuminuria, carotid intima media thickness, and stronger traditional Indian beliefs.
Conclusions: Indian immigrants may be more likely to have diabetes than other U.S. ethnic groups, and cultural factors may play a role, suggesting that this is a promising area of research.

Introduction

Currently, India has the second largest number of individuals with type 2 diabetes globally, with projections of India leading the world with approximately 79.4 million people with diabetes in 2030.[1] Consistent with these statistics, several studies from the South Asian diaspora have found South Asians (individuals from India, Pakistan, Bangladesh, Nepal, and Sri Lanka) have 2- to 4-fold increased prevalence of type 2 diabetes compared to other ethnic groups.[2–5] Only a few studies have systematically measured diabetes prevalence among South Asians in the United States,[6–8] but none have used the 2-h glucose tolerance as a diagnostic test.

South Asians may have increased genetic susceptibility to diabetes,[9] which is further enhanced by environmental triggers such as physical inactivity, excessive caloric intake, and obesity. Less attention has been paid to specific cultural factors that may also increase diabetes risk.

We aimed to determine the prevalence and correlates of type 2 diabetes and prediabetes in a population-based sample of South Asian Indians from the San Francisco Bay Area. We used similar sampling methods, eligibility criteria, clinical and laboratory measures to the Multi-Ethnic Study of Atherosclerosis (MESA) to efficiently compare risk factor associations between the South Asian Indians and

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four other major ethnic groups in the United States. We also explored metabolic, sociocultural, lifestyle, and novel risk factors associated with diabetes or prediabetes among the Indian-American population.

Materials and Methods

We conducted a pilot population-based study called the Metabolic Syndrome and Atherosclerosis in South Asians Living in America (MASALA) study. We enrolled 150 participants from the San Francisco Bay Area between August, 2006, and October, 2007. This study was modeled on the MESA and used similar recruitment methods, eligibility criteria, questionnaire, and clinical measurements.[10] To be eligible, participants had to be between age 45 and 84 years and self-identify as South Asian Indian (hereafter referred to as "Indian"). We excluded individuals from other South Asian countries, except for India, due to the small sample size of this study. To be consistent with MESA, we excluded individuals with physician-diagnosed heart attack, stroke, transient ischemic attack, congestive heart failure, angina, past coronary artery bypass graft surgery, angioplasty, valve replacement, pacemaker or defibrillator implantation, surgery on the heart or arteries, or atrial fibrillation on electrocardiogram. Individuals using nitroglycerin, those under active cancer treatment, with impaired cognitive ability, life expectancy less than 5 years, plans to move, or living in a nursing home were also excluded. We excluded persons who could not speak or understand Hindi or English.

Our sampling frame was created using the South Asian surnames on the California Health Interview Survey. Using this surname sampling frame, we obtained name, address, and telephone number from randomly sampled households from the Bay Area using a commercial mailing list company (Genesys Marketing System Group, Washington, PA). We mailed letters and conducted phone calls to assess study eligibility. After mailing 3,484 letters, we were unable to contact 1,897 (54.4%) of families by phone. Of approximately 1,587 households reached by phone, 1,091 (68.7%) did not have an eligible member primarily due to young age. Another 346 (21.8%) were not interested, of whom approximately 98 (28%) were eligible for the study. Of all eligible persons, we enrolled 150/248 (60.5%) in the study. This rate is similar to the MESA Exam 1 participation rate (59.8%) of those screened and deemed eligible.

Participants completed questionnaires to ascertain medical history, smoking and alcohol use, and physical activity. We assessed macronutrient intake with the SHARE Food Frequency Questionnaire, which was developed and validated in South Asians.[11] We excluded 4 participants who did not satisfy the *a priori* criteria of reporting daily energy intake of 3.3–17.6 MJ (800–4,200 kcal/24 h). Intake of fat, carbohydrates, and protein was expressed as nutrient density.[12] We developed a 7-item scale from prior qualitative research to examine traditional Indian beliefs. The base question was "How much would you wish these Indian traditions would be practiced in America in the future?" These seven items included: Performing religious ceremonies; serving sweets at ceremonies; fasting on specific occasions; living in a joint family; having an arranged marriage; eating a staple diet of rice, chapatis, vegetables, and yogurt; using spices for health and healing. The items were scored on a Likert scale with scores from 7 to 18 representing strong traditional Indian beliefs, 19 to 24 moderate traditional beliefs, and 25 to 35 weak traditional beliefs. The Cronbach alpha for this scale was 0.79 with good reliability and validity.

Participant weight was measured on a standard balance beam scale and height with a stadiometer. Waist circumference was measured using a Gullick II tape at the site of maximum circumference midway between the lower ribs and the anterior superior iliac spine. Three seated blood pressure measurements were obtained with an automated blood pressure monitor (Philips-Agilent V24C, Andover, MA). Mean systolic blood pressure (SBP) and diastolic blood pressure (DBP) were calculated from the second and third blood pressure measurement.

After a 12-h fast, blood samples were obtained. Total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-C) was measured by enzymatic methods and alaninine aminotransferase (ALT) by kinetic methods (Quest, San Jose, CA). Microalbumin was measured from urine samples with the Beckman-Coulter Immunochemistry Analyzer (Beckman Instruments, Brea, CA). Spot urine albumin-to-creatinine ratios (ACR) with sex-specific cutpoints were used to define microalbuminuria.[13] Participants were administered 75 grams of oral glucose with blood samples taken at 120 min for plasma glucose (YSI 2300, Yellow Sprints, OH) and insulin (RIA, Millipore, St. Charles, MO).

Total lean and fat mass was assessed using dual-energy X-ray absorptiometry (Hologic Discovery-Wi, Waltham, MA). Computed tomography (CT; Philips Medical Systems, Best, The Netherlands) was used to determine abdominal visceral and subcutaneous fat area. A trained radiology technician used a lateral scout image of the spine to establish the correct position (between the L4 and L5 vertebrae) for the abdominal CT using standardized protocols. Visceral and subcutaneous abdominal fat were measured at the L4–L5 level after participants were positioned supine. All CT scans were digitally recorded for batched readings by a trained research assistant. Intraabdominal adipose tissue area was quantified by delineating the intraabdominal cavity at the innermost aspect of the abdominal and oblique muscle walls surrounding the cavity. Subcutaneous adipose tissue area was quantified by highlighting of adipose tissue located between the skin and the outermost aspect of the abdominal muscle wall.

We also obtained nonenhanced CT images of liver and spleen density to quantify hepatic fat content. CT measurements included minimal, maximal, and mean attenuation at a minimum of two liver sites and one spleen measurement. A liver minus spleen attenuation difference less than or equal to −10 Hounsfield Units (HU) is diagnostic for fatty liver, or a liver attenuation greater than or equal to spleen attenuation excludes fatty liver.[14–16]

Carotid ultrasound examination was performed using a 8-MHz linear array transducer with an Acuson Sequoia 512 Imaging System (Siemens Medical Solutions, Mountain View, CA). A trained vascular technician located the carotid artery bifurcation and identified the maximal wall thickening in the near and far wall. Each image was digitally recorded and mailed to the reading center where maximal intimal medial thickness (IMT) of the internal and common carotid was measured as the mean of the maximum IMT of the near and far walls on both sides.

Individuals were categorized with normal glucose tolerance, prediabetes, or diabetes. Diabetes was defined by use of a hypoglycemic medication, or fasting plasma glucose (FPG) ≥126 mg/dL, or 2-h postchallenge glucose ≥200 mg/dL.[17] Prediabetes was defined by FPG 100–125 mg/dL and/or a 2-h postchallenge glucose between 140–199 mg/dL. Normal glucose-tolerant participants had both FPG <100 mg/dL and 2-h glucose <140 mg/dL. Because the MESA study participants did not have 2-h glucose tolerance tests performed, in our diabetes prevalence comparison to MESA, we exclude the use of the 2-h postchallenge test results.

Statistical analysis

Characteristics of the MASALA participants were compared by glucose tolerance category using the chi-square test, analysis of variance (ANOVA), or Kruskal–Wallis tests as appropriate. After excluding the 2-h glucose tolerance test, the odds of diabetes was compared between Indians and each MESA ethnic group by logistic regression after adjusting for age and other covariates, including sex, education, income, smoking, alcohol use, exercise, body mass index (BMI), waist circumference, hypertension, HDL-C, and triglycerides. We calculated unadjusted, age-adjusted, and multivariate-adjusted prevalence rates of diabetes comparing the Indians to all four MESA ethnic groups. In a sensitivity analysis, we compared the prevalence of drug-treated diabetes participants only.

We used proportional odds regression models to examine covariates associated with an ordinal scale consisting of no diabetes, prediabetes, and diabetes outcome among the Indians. The odds ratio (OR) estimated for a predictor under this model captures its association with both diabetes versus normal glucose tolerance or prediabetes, and with diabetes or prediabetes versus normal glucose tolerance, under the assumption that the OR are the same for both dichotomous outcomes.[18] Model assumption of proportional odds was checked using the chi-squared0 score test. To keep only the most relevant covariates, we used stepwise backward elimination to remove variables with $P > 0.20$ from the model. Spearman correlations were examined among potential covariates to reduce the likelihood of multicollinearity. We used STATA (version 9.0, College Station, TX) and SAS Version 9.1 (SAS Institute, Cary, NC) for our analyses.

Results

Of the 150 Indians in the MASALA study, 43 (29%) had type 2 diabetes, 56 (37%) had prediabetes, and the remaining 51 (34%) had normal glucose tolerance. All but 2 were immigrants to the United States. Of those with diabetes, 21 (49%) were using hypoglycemic medications; only 2 were using insulin. Those with treated diabetes had a diabetes duration of 12 (1–26) years. Of the 56 participants with prediabetes, 21 (37%) had both impaired fasting glucose (IFG; FPG 100–125 mg/dL) and impaired glucose tolerance (IGT, 2-h glucose 140–199 mg/dL), whereas 11 (20%) had isolated IFG, and the remaining 24 (43%) had isolated IGT.

Table 1 shows participant characteristics by glucose tolerance status. Individuals with diabetes were more likely to be male, have moderate/strong traditional Indian beliefs, higher SBP and DBP, BMI, waist circumference, visceral fat area, total lean mass, and carotid IMT. Fasting glucose, insulin, triglycerides, ALT, creatinine, and microalbuminuria were significantly higher, whereas HDL-C and adiponectin levels were lower among those with diabetes compared to the other groups. Both measures of socioeconomic status, education, and family income, were not associated with diabetes. There were trends toward lower energy intake from carbohydrates and higher protein intake among individuals with diabetes compared to the other groups.

Table 2 shows baseline characteristics of the four MESA ethnic groups compared to the Indian Americans. Because MASALA participants were a mean 3–5 years younger than MESA groups, all characteristics were adjusted for age. Indians had significantly higher socioeconomic attainment, lower smoking rates, and BMI than most ethnic groups except for Chinese Americans. Age-adjusted prevalence of diabetes was higher in Indians compared to whites and Chinese Americans. Because MESA participants did not perform 2-h glucose tolerance testing, we restricted the MASALA study diabetes definition to the use of hypoglycemic medication or a FPG ≥126 mg/dL.

We compared the adjusted odds of diabetes of the MASALA study participants to the MESA ethnic groups. After adjusting for covariates associated with diabetes, including age, sex, education, family income, smoking, alcohol use, exercise, waist circumference, hypertension, HDL-C, and triglycerides, compared to Indians, all of the MESA ethnic groups had significantly lower odds of diabetes: Whites [OR, 0.17; 95% confidence interval (CI), 0.11–0.27]; Latinos (OR, 0.37; CI, 0.23–0.59); African Americans (OR, 0.50; CI, 0.31–0.78); Chinese Americans (OR, 0.55; CI, 0.34–0.88). Further adjustment for microalbuminuria and internal carotid IMT attenuated the results somewhat: Indians (OR, 1.0); whites (OR, 0.29; 95% CI, 0.17–0.49); Latinos (OR, 0.59; 95% CI, 0.34–1.00); African Americans (OR, 0.77; 95% CI, 0.45–1.32); Chinese Americans (OR, 0.78; CI, 0.45–1.32). Among those with medication-treated diabetes, Indians had higher adjusted prevalence than most MESA ethnic groups (12% Indians; 3% whites; 10% Chinese Americans; 11% African Americans; and 10% Latinos; $P < 0.05$ for each comparison except for African Americans).

In the proportional odds model (Table 3), metabolic covariates significantly associated with higher odds or prediabetes or diabetes included hypertension and lower liver minus spleen attenuation values. Higher levels of ALT and visceral fat area had a trend toward increased odds as well. Having moderate/strong traditional Indian beliefs was independently associated with increased odds of prediabetes or diabetes. Other more novel covariates included microalbuminuria and increased internal carotid IMT.

We further examined the traditional Indian beliefs measure to determine which aspects of this construct were most associated with the increased diabetes risk (data not shown). Of the seven items that comprised that scale, the items about continuing the tradition of serving sweets at religious ceremonies, fasting on specific occasions, and having an arranged marriage were most strongly associated with increased diabetes risk.

Discussion

In this pilot study of South Asian Indians from the San Francisco Bay Area modeled on the MESA study, we found that Indians have somewhat higher adjusted odds of type 2 diabetes than other ethnic groups in the United States, despite having lower BMI and higher socioeconomic attainment. Correlates most associated with prediabetes

Table 1. Characteristics of the MASALA Participants,[a] 2006–2007

	Normal glucose tolerance n = 51	*Prediabetes n = 56*	*Diabetes n = 43*	*P value*
Male sex, %	29	53	72	<0.001
Age, years	56 ± 7	57 ± 9	58 ± 7	0.72
Years lived in the United States	23 ± 10	24 ± 11	24 ± 13	0.80
Education				
≤ High school, %	12	9	16	0.45
≤ Bachelor's degree	27	39	40	
> Bachelor's degree	61	52	44	
Family income				
≤$40,000, %	10	14	23	0.39
$40,000–74,999	14	23	16	
$75,000–99,999	18	15	9	
≥$100,000	59	46	51	
Current smoking, %	6	4	2	0.38
Total alcoholic drinks/week	1.5 ± 4.0	3.2 ± 5.5	3.5 ± 5.8	0.12
Total exercise (MET-min/week)	2328 ± 3054	1883 ± 1582	2001 ± 2265	0.61
Traditional Indian beliefs, %				
Weak	45	30	16	0.03
Moderate	28	42	37	
Strong	28	28	47	
Systolic blood pressure, mmHg	116 ± 16	127 ± 16	132 ± 14	<0.001
Diastolic blood pressure, mmHg	68 ± 9	74 ± 11	76 ± 11	0.003
Hypertension, %	20	42	72	<0.001
Body composition measures				
Body mass index, kg/m^2	24.5 ± 3.6	27.0 ± 5.2	26.9 ± 4.6	0.01
Waist circumference, cm	90.9 ± 11.2	96.9 ± 12.7	101.4 ± 11.1	<0.001
Abdominal visceral fat area, cm^2	105 ± 46	136 ± 51	163 ± 59	<0.001
Abdominal subcutaneous fat, cm^2	233 ± 94	264 ± 132	257 ± 106	0.34
Percent body fat, %	36.1 ± 6.4	35.0 ± 8.8	34.0 ± 8.6	0.44
Total body fat, kg	23.1 ± 6.9	25.1 ± 9.1	25.7 ± 8.0	0.24
Total lean mass, kg	38.6 ± 9.2	43.8 ± 9.5	47.2 ± 9.2	<0.001
Liver–spleen attenuation, HU	15.6 ± 7.7	10.4 ± 9.2	3.4 ± 12.6	<0.001
Food frequency questionnaire data				
Total calories, kcal/day	1,801 ± 651	2,015 ± 697	1,935 ± 732	0.22
Carbohydrates, % of energy intake	52 ± 6	53 ± 5	50 ± 5	0.06
Total protein, % of energy intake	14 ± 3	14 ± 3	15 ± 3	0.10
Total fat, % of energy intake	31 ± 6	35 ± 9	34 ± 9	0.47
Total cereal fiber, g/day	11.6 ± 4.5	13.2 ± 6.2	12.9 ± 6.1	0.37
Laboratory measures				
Fasting glucose, mg/dL	86 ± 6	95 ± 10	131 ± 28	<0.001
2-h glucose, mg/dL	107 ± 16	151 ± 27	279 ± 65	<0.001
Fasting insulin, μU/mL	9.8 ± 4.3	13.4 ± 8.8	19.3 ± 21.0	0.002
Total cholesterol, mg/dL	193 ± 31	186 ± 32	185 ± 37	0.42
HDL-C, mg/dL	53 ± 14	48 ± 14	45 ± 11	0.008
Triglycerides, mg/dL	115 ± 39	135 ± 67	151 ± 75	0.02
LDL-C, mg/dL	116 ± 27	111 ± 29	110 ± 36	0.57
ALT, mg/dL	17 ± 7	20 ± 9	30 ± 24	<0.001
Creatinine, mg/dL	0.8 ± 0.2	1.0 ± 0.2	1.0 ± 0.2	0.004
CRP, μg/mL	1.5 ± 1.6	3.6 ± 5.2	2.1 ± 2.1	0.16
Total adiponectin, μg/mL	8.5 ± 4.7	6.9 ± 4.0	6.4 ± 6.1	0.002
Microalbuminuria, %	2 ± 1	14 ± 35	37 ± 49	<0.001
Subclinical atherosclerosis				
Common carotid IMT, mm	0.86 ± 0.1	0.94 ± 0.2	0.96 ± 0.2	0.02
Internal carotid IMT, mm	0.88 ± 0.3	0.99 ± 0.3	1.16 ± 0.5	0.001

[a]Values represent mean ± SD or %; *P* values using chi-squared, ANOVA, or Kruskall–Wallis test as appropriate.

Abbreviations: MASALA, Metabolic Syndrome and Atherosclerosis in South Asians Living in America Study; HU, Hounsfield units; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; ALT, alaninine aminotransferase; CRP, C-reactive protein; IMT, intimal medial thickness.

Table 2. Age-Adjusted Characteristics of MASALA and MESA Participants by Ethnic Group on Measures Collected by Both Studies

	South Asian Indians n = 150	*Whites n = 2,507*	*Chinese Americans n = 769*	*African American n = 1,821*	*Latinos n = 1,429*
Age, years	57 ± 8	62 ± 10[a]	61 ± 10[a]	61 ± 9[a]	60 ± 4[a]
Male sex, %	50	48	49	45	48
Education ≥ bachelor's degree, %	75	51[a]	39[a]	34[a]	10[a]
Family income ≥ $75,000, %	65	36[a]	17[a]	17[a]	7[a]
Current smoking, %	3	11[a]	5	18[a]	13[a]
Alcoholic drinks ≥7 per week, %	10	21[a]	2[a]	14	15
Exercise, MET-min/week[b]	1,327	1,873[a]	1,240	1,679[a]	1,219
BMI, kg/m^2	26 ± 5	28 ± 5[c]	24 ± 3[c]	30 ± 6[c]	29 ± 5[c]
Waist circumference, cm	96 ± 12	98 ± 15	87 ± 10[c]	101 ± 15[c]	101 ± 13[c]
LDL-C, mg/dL	112 ± 31	117 ± 30	115 ± 29	117 ± 33	120 ± 33[c]
HDL-C, mg/dL	49 ± 15	52 ± 16[c]	49 ± 13	52 ± 15[c]	48 ± 13
Triglycerides, mg/dL[b]	119	114	124	90[c]	135[c]
Fasting insulin, µU/mL[b]	11.0	4.9[a]	5.1[a]	6.0[a]	6.6[a]
Urinary microalbumin, mg/dL[b]	0.40	0.46	0.72[a]	0.80[a]	0.87[a]
Internal carotid intima media thickness, mm	1.0	0.98	0.78	0.96	0.92[c]
Hypertension, %	48	35[c]	34[c]	60[c]	41
Metabolic syndrome, %	41%	30%[c]	26%[a]	36%	43%
Diabetes,[d] %	26	7[c]	14[c]	19	19
Impaired fasting glucose	25	25	33	28	30
Normal fasting glucose	48	68	53	53	51

[a]Compares each individual ethnic group in MESA to Indian Americans, $P < 0.001$.
[b]Age-adjusted median or geometric mean values displayed.
[c]Compares each individual ethnic group in MESA to Indian Americans, $P < 0.05$.
[d]Diabetes is defined as fasting glucose ≥126 mg/dL and/or taking diabetes medications; impaired fasting glucose: 100–125 mg/dl; normal glucose <100 mg/dL.
Abbreviations: MASALA, Metabolic Syndrome and Atherosclerosis in South Asians Living in America; MESA, Multi-Ethnic Study of Atherosclerosis; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.

and diabetes among Indians included hypertension, fatty liver, visceral adiposity, microalbuminuria, higher levels of carotid IMT, and stronger traditional Indian beliefs.

Our sample estimate of 29% diabetes prevalence in Indians between age 45 and 79 years is comparable to South Asian estimates taken from a broader age range of adults around the world. Recent diabetes prevalence estimates among adults aged 20 years or older are approximately 14.3%–18.6% in an urban city in South India.[19,20] Population-based samples of South Asians from the United Kingdom have reported a diabetes prevalence of 11.2%–21.4%.[2,21] A recent population-based sample of Asian Indians in the United States that used only fasting glucose and self-report of treated diabetes found an diabetes prevalence of 17% in their sample (age >18 years).[6] However, the prevalence of diabetes in the MASALA study likely underestimates the true prevalence of diabetes in the U.S. South Asian Indian population because we excluded individuals with a history of cardiovascular disease from our sample.

Table 3. Multivariate Model of Correlates Associated With Diabetes and Prediabetes Among South Asian Indians in the MASALA Study

	Odds ratio (95% CI)	*P value*
Hypertension	3.31 (1.49–7.33)	<0.001
Microalbuminuria	4.72 (1.42–14.70)	0.007
Liver/spleen attenuation, HU	0.50 (0.31–0.81)	0.005
Internal carotid IMT, per SD mm	1.92 (1.26–2.94)	0.002
Traditional Indian beliefs, moderate/strong versus weak	2.32 (1.03–5.22)	0.04
ALT, per SD mg/dL	1.81 (1.08–3.06)	0.03
Visceral fat area, per SD cm^2	1.57 (0.99–2.48)	0.06
Sex, male versus female	1.38 (0.57–3.35)	0.48

Abbreviations: HU, Houndsfield unit; IMT, intimal medial thickness; SD, standard deviation; ALT, alaninine aminotransferase.

Obesity is a well-known determinant of type 2 diabetes. Central adiposity measured with waist circumference, sagittal diameter, or abdominal visceral fat by CT have been more closely associated with glucose abnormalities than overall adiposity measured by BMI.[22–24] In the present study, visceral adiposity was most closely associated with prediabetes and diabetes, whereas overall adiposity measured with BMI or total body fat from whole body DEXA were not associated. This is a critical clinical finding because clinicians who focus on body weight to guide their screening practices or lifestyle recommendations will miss patients if they do not use a measurement of visceral adiposity, such as waist circumference, in their clinical encounters.

One of the strongest correlates of prediabetes and diabetes was higher levels of internal carotid IMT. There may be important ethnic differences in the associations between carotid IMT and glucose tolerance. Our findings are consistent with a large South Indian study that found that Indians with impaired and diabetic glucose tolerance had significantly higher mean IMT than those with normal glucose tolerance.[20] This finding contrasts with the Insulin Resistance Atherosclerosis Study, which included whites, African Americans, and Latinos and reported no difference in IMT values between those with normal and impaired glucose tolerance.[25] An explanation for this ethnic difference could be the degree of insulin resistance in the South Asians versus the other ethnic groups that may lead to greater endothelial dysfunction[26] and earlier subclinical atherosclerosis.[27,28] This finding supports the "ticking clock" hypothesis[29] that cardiovascular disease may begin before the onset of clinical diabetes in Indians.

Two other factors associated with diabetes and prediabetes were fatty liver and microalbuminuria. Nonalcoholic fatty liver disease has been associated with insulin resistance and type 2 diabetes,[30,31] although it is debated whether fatty liver is a risk marker or a risk factor. Microalbuminuria has been linked with increased vascular permeability, systemic inflammation, endothelial dysfunction, and abnormalities of coagulation and fibrinolysis.[32] Microalbuminuria is more prevalent among South Asians with diabetes compared to Europeans,[33,34] but less is known about the prevalence of microalbuminuria in nondiabetic South Asians. Our findings support results in other ethnic groups where microalbuminuria is found in prediabetes.[32]

An intriguing finding was that individuals with more moderate or strong traditional Indian beliefs were more likely to have prediabetes or diabetes than those with weaker traditional beliefs. Assimilation into a Western lifestyle is generally associated with worsening health outcomes,[36,37] while retention of traditional lifestyles and dietary patterns has been protective.[38] Continuing the tradition of serving Indian sweets, having an arranged marriage, and fasting on specific occasions were items most associated with diabetes. Those with stronger traditional Indian beliefs were more likely to have a higher proportion of carbohydrate intake, which is consistent with the wish to maintain the Indian tradition of serving sweets. Fasting may promote the "thrifty gene" phenotype[39] and, through compensatory feedback mechanisms through the central nervous system, promote the storage of energy into adipose tissue stores.[40] The tradition of arranged marriage may be linked to other traditional dietary or genetic factors that promote diabetes. This construct of traditional Indian beliefs needs further study because this may hold a key to potentially modifiable behaviors that can lower diabetes risk.

Although we measured several traditional and novel risk factors for diabetes in this Indian sample, we are limited in interpretation given the small sample size and cross-sectional nature of the study. The MASALA study was created with parallel methods to MESA, but because the participants were sampled from a non-MESA site in the San Francisco Bay Area, it is possible that the MASALA sample may not be directly comparable to MESA. Fasting glucose was measured in different laboratories for the MASALA and MESA study that may account for some differences in diabetes prevalence between the two studies. While the MASALA participants had significantly higher socioeconomic attainment than all four MESA ethnic groups, this may not be unique to Indians living in the Bay Area as a similar socioeconomic distribution has been reported among Indian Americans in the U.S. Census 2000.[41] But higher socioeconomic status is a protective factor in westernized cultures associated with lower diabetes prevalence.[42,43] Adjusting for SES only exaggerated the prevalence differences between the Indians and other ethnic groups. Last, we were unable to compare diabetes estimates with other high-risk ethnic groups such as Native Americans.

In conclusion, we found that Indian immigrants in the United States have somewhat higher odds of type 2 diabetes compared to other ethnic groups after adjusting for well-known determinants of diabetes. Several metabolic measures, including hypertension, fatty liver disease, and visceral adiposity, were correlated with prediabetes and diabetes among South Asian Indians, as well as markers of subclinical atherosclerosis, including internal carotid IMT and microalbuminuria. Having moderate or strong Indian traditional beliefs was an independent risk factor that may be modifiable to curb the high rates of diabetes in this ethnic group.

Acknowledgments

A.M.K. was funded by K23 HL080026-01, the University of California, San Francisco Research Evaluation and Allocation Committee, and by National Institutes of Health/ National Center for Research Resources (NIH/NCRR) UCSF-CTSI Grant Number UL1 RR024131-01. The MESA study was funded by contracts #N01-HC-95159, N01-HC-95169, and N01-HC-95166 from the National Heart, Lung, and Blood Institute. The sponsors did not play a significant role in the analysis, interpretation, and presentation of these results.

Author Disclosure Statement

No competing financial interests exist.

References

1. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030. *Diabetes Care* 2004;27:1047–1053.
2. Simmons D, Williams DR, Powell MJ. The Coventry Diabetes Study: Prevalence of diabetes and impaired glucose tolerance in Europids and Asians. *Q J Med* 1991;81:1021–1030.
3. Guidelines for the management of diabetes mellitus in Singapore. National Diabetes Commission, Singapore. *Singapore Med J* 1993;34(6 Suppl):S1–S35.
4. Anand SS, Yusuf S, Vuksan V, Devanesen S, Teo KK, Montague PA, Kelemen L, Yi C, Lonn E, Gerstein H, Hegele RA, McQueen M. Differences in risk factors, atherosclerosis, and cardiovascular disease between ethnic groups in Canada: The Study of Health Assessment and Risk in Ethnic groups (SHARE). *Lancet* 2000;356:279–284.
5. Abate N, Chandalia M. The impact of ethnicity on type 2 diabetes. *J Diabetes Complications* 2003;17:39–58.
6. Misra R, Patel T, Kotha P, Raji A, Ganda O, Banerji M, Shah V, Vijay K, Mudaliar S, Iyer D, Balasubramanyam A. Prevalence of diabetes, metabolic syndrome, and cardiovascular risk factors in US Asian Indians: Results from a national study. *J Diabetes Complications* 2009 Mar 18. [Epub ahead of print] .
7. Mohanty SA, Woolhandler S, Himmelstein DU, Bor DH. Diabetes and cardiovascular disease among Asian Indians in the United States. *J Gen Intern Med* 2005;20:474–478.
8. Venkataraman R, Nanda NC, Baweja G, Parikh N, Bhatia V. Prevalence of diabetes mellitus and related conditions

in Asian Indians living in the United States. *Am J Cardiol* 2004;94:977–980.

9. Radha V, Mohan V. Genetic predisposition to type 2 diabetes among Asian Indians. *Indian J Med Res* 2007;125:259–274.
10. Bild DE, Bluemke DA, Burke GL, Detrano R, Diez Roux AV, Folsom AR, Greenland P, Jacob DR, Jr., Kronmal R, Liu K, Nelson JC, O'Leary D, Saad MF, Shea s, Szklo M, Tracy RP. Multi-ethnic study of atherosclerosis: objectives and design. *Am J Epidemiol* 2002;156:871–881.
11. Kelemen LE, Anand SS, Vuksan V, Yi Q, Teo KK, Devanesen S, Yusuf S. Development and evaluation of cultural food frequency questionnaires for South Asians, Chinese, and Europeans in North America. *J Am Diet Assoc*. 2003;103:1178–1184.
12. Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. *Am J Clin Nutr* 1997;65(4 Suppl):1220S–1228S; discussion 1229S-1231S.
13. Mattix HJ, Hsu CY, Shaykevich S, Curhan G. Use of the albumin/creatinine ratio to detect microalbuminuria: implications of sex and race. *J Am Soc Nephrol* 2002;13:1034–1039.
14. Jacobs JE, Birnbaum BA, Shapiro MA, Langlotz CP, Slosman F, Rubesin SE, Horii SC. Diagnostic criteria for fatty infiltration of the liver on contrast-enhanced helical CT. *AJR Am J Roentgenol* 1998;171:659–664.
15. Ricci C, Longo R, Gioulis E, Bosco M, Pollesello P, Masutti F, Croce LS, Paoletti S, de Bernard B, Tiribellia C, Dalla Palma L. Noninvasive in vivo quantitative assessment of fat content in human liver. *J Hepatol*. 1997;27:108–113.
16. Piekarski J, Goldberg HI, Royal SA, Axel L, Moss AA. Difference between liver and spleen CT numbers in the normal adult: Its usefulness in predicting the presence of diffuse liver disease. *Radiology* 1980;137:727–729.
17. Screening for diabetes. *Diabetes Care* 2003;26(Suppl 1)):S21–S24.
18. Scott SC, Goldberg MS, Mayo NE. Statistical assessment of ordinal outcomes in comparative studies. *J Clin Epidemiol* 1997;50:45–55.
19. Ramachandran A, Mary S, Yamuna A, Murugesan N, Snehalatha C. High prevalence of diabetes and cardiovascular risk factors associated with urbanization in India. *Diabetes Care* 2008;31:893–898.
20. Mohan V, Deepa M, Deepa R, Shanthirani CS, Farooq S, Ganesan A, Datta M. Secular trends in the prevalence of diabetes and impaired glucose tolerance in urban South India—the Chennai Urban Rural Epidemiology Study (CURES-17). *Diabetologia* 2006;49:1175–1178.
21. Unwin N, Alberti KG, Bhopal R, Harland J, Watson W, White M. Comparison of the current WHO and new ADA criteria for the diagnosis of diabetes mellitus in three ethnic groups in the UK. American Diabetes Association. *Diabet Med* 1998;15:554–547.
22. McKeigue PM, Shah B, Marmot MG. Relation of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in South Asians. *Lancet*. 1991;337(8738):382–6.
23. Banerji MA, Faridi N, Atluri R, Chaiken RL, Lebovitz HE. Body composition, visceral fat, leptin, and insulin resistance in Asian Indian men. *J Clin Endocrinol Metab* 1999;84:137–144.
24. Raji A, Seely EW, Arky RA, Simonson DC. Body fat distribution and insulin resistance in healthy Asian Indians and Caucasians. *J Clin Endocrinol Metab* 2001;86:5366–5371.
25. Wagenknecht LE, D'Agostino RB, Jr., Haffner SM, Savage PJ, Rewers M. Impaired glucose tolerance, type 2 diabetes, and carotid wall thickness: The Insulin Resistance Atherosclerosis Study. *Diabetes Care* 1998;21:1812–1818.
26. Steinberg HO, Chaker H, Leaming R, Johnson A, Brechtel G, Baron AD. Obesity/insulin resistance is associated with endothelial dysfunction. Implications for the syndrome of insulin resistance. *J Clin Invest*. 1996;97:2601–2610.
27. Chambers JC, McGregor A, Jean-Marie J, Kooner JS. Abnormalities of vascular endothelial function may contribute to increased coronary heart disease risk in UK Indian Asians. *Heart* 1999;81:501–504.
28. Jadhav UM. Endothelium-dependent brachial artery flow-mediated vasodilatation in patient with diabetes mellitus with and without coronary artery disease. *J Assoc Physicians India* 2003;51:736; author reply 736–737.
29. Haffner SM, Stern MP, Hazuda HP, Mitchell BD, Patterson JK. Cardiovascular risk factors in confirmed prediabetic individuals. Does the clock for coronary heart disease start ticking before the onset of clinical diabetes? *JAMA* 1990;263:2893–2898.
30. Shibata M, Kihara Y, Taguchi M, Tashiro M, Otsuki M. Nonalcoholic fatty liver disease is a risk factor for type 2 diabetes in middle-aged Japanese men. *Diabetes Care* 2007;30: 2940–2944.
31. Hanley AJ, Williams K, Festa A, Wagenknecht LE, D'Agostino RB, Jr., Kempf J, Zinman B, Haffner SM. Elevations in markers of liver injury and risk of type 2 diabetes: The insulin resistance atherosclerosis study. *Diabetes* 2004;53:2623–2632.
32. Festa A, D'Agostino R, Howard G, Mykkanen L, Tracy RP, Haffner SM. Inflammation and microalbuminuria in nondiabetic and type 2 diabetic subjects: The Insulin Resistance Atherosclerosis Study. *Kidney Int* 2000;58:1703–1710.
33. Mather HM, Chaturvedi N, Kehely AM. Comparison of prevalence and risk factors for microalbuminuria in South Asians and Europeans with type 2 diabetes mellitus. *Diabet Med* 1998;15:672–677.
34. Dixon AN, Raymond NT, Mughal S, Rahim A, O'Hare JP, Kumar S, Barnett AH. Prevalence of microalbuminuria and hypertension in South Asians and white Europeans with type 2 diabetes: A report from the United Kingdom Asian Diabetes Study (UKADS). *Diab Vasc Dis Res* 2006;3:22–25.
35. Groop L, Forsblom C, Lehtovirta M. Characterization of the prediabetic state. *Am J Hypertens*. 1997;10(9 Pt 2):172S–180S.
36. Kandula NR, Diez-Roux AV, Chan C, Daviglus ML, Jackson SA, Ni H, Schreiner PJ. Association of acculturation levels and prevalence of diabetes in the multi-ethnic study of atherosclerosis (MESA). *Diabetes Care* 2008;31:1621–1628.
37. Gilbert PA, Khokhar S. Changing dietary habits of ethnic groups in Europe and implications for health. *Nutr Rev* 2008;66:203–215.
38. Perez-Escamilla R, Putnik P. The role of acculturation in nutrition, lifestyle, and incidence of type 2 diabetes among Latinos. *J Nutr* 2007;137:860–870.
39. Neel JV. Diabetes mellitus: A "thrifty" genotype rendered detrimental by "progress"? *Am J Hum Genet* 1962;14:353–362.
40. Schwartz MW. Central nervous system regulation of food intake. *Obesity (Silver Spring)* 2006;14(Suppl 1):1S–8S.
41. Rangaswamy P, Kalayil AL. Making Data Count: South Asian Americans in the 2000 Census with focus on Illinois. 2005.
42. Nazroo JY. South Asian people and heart disease: An assessment of the importance of socioeconomic position. *Ethn Dis* 2001;11:401–411.
43. Robbins JM, Vaccarino V, Zhang H, Kasl SV. Socioeconomic status and type 2 diabetes in African American and non-Hispanic white women and men: evidence from the Third National Health and Nutrition Examination Survey. *Am J Public Health* 2001;91:76–83.

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