



Prevalence of diabetes, metabolic syndrome, and cardiovascular risk factors in US Asian Indians: results from a national study

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Received 22 July 2008; received in revised form 23 November 2008; accepted 6 January 2009

Abstract

Background: Although studies of immigrant Asian Indians in other countries show high rates of diabetes (DM), metabolic syndrome (MetS), and cardiovascular disease (CVD), no randomized, population-based studies of this rapidly growing ethnic group exist in the US. **Methods:** The sample comprised 1038 randomly selected Asian Indian immigrants, aged 18 years and older at seven US sites. Prevalence of diabetes and MetS (age-adjusted and sex-adjusted means) was estimated and ANOVA was used to calculate gender and group differences (normoglycemia/impaired fasting glucose/diabetes) for CVD risk factors. **Results:** The mean age was 48.2 years. The majority of respondents were male, married, educated, and with some form of health insurance. Prevalence of diabetes was 17.4%, and 33% of the respondents had prediabetes. Cardiovascular risk factors, especially high levels of triglycerides, total cholesterol, LDL cholesterol, homocysteine, and C-reactive protein, and low levels of HDL cholesterol, were also prevalent; elevated lipoprotein(a) was not observed. The age-adjusted prevalence of MetS was 26.9% by the original NCEP/ATP III criteria, 32.7% by the modified NCEP/ATP III criteria, and 38.2% by the IDF criteria. The MetS rates for women, but not for men, increased with age using all three criteria. There was a progressive worsening of all metabolic parameters as individuals progressed from normal to IFG to diabetes. **Conclusion:** The prevalence rates of diabetes and MetS among US Asian Indians are higher than reported in earlier, nonrandomized, smaller surveys. These data provide a firm basis for future mechanistic and interventional studies.

Published by Elsevier Inc.

Keywords: Diabetes prevalence; Asian Indian; CVD risk factors; Metabolic syndrome

1. Introduction

Migrant Asian Indians are reported to have high rates of diabetes (DM), metabolic syndrome (MetS), cardiovascular

disease (CVD), and related complications in the US, Canada, and UK (Anand et al., 2000; Chandie Shaw et al., 2002; Enas et al., 1996; Hughes et al., 1997; McKeigue et al., 1993, 1992; Mohanty et al., 2005; Omar et al., 1985; Ramaiya et al., 1995; Samanta et al., 1991). Insulin resistance is highly prevalent in Asian Indian migrants, despite low rates of obesity (McKeigue, 1996; McKeigue et al., 1992; Whincup et al., 2002). In the United

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States, Asian Indians have the highest ethnic-specific prevalence of CVD, with age-specific mortality two to three times higher than Caucasians (Enas & Senthilkumar, 2001; Enas et al., 1996; Wild et al., 1995). Traditional risk factors such as hypertension, obesity, and hypercholesterolemia do not account completely for these high rates. Prevalence of DM and related conditions among US Asian Indians was assessed by Venkataraman et al. (2004) using a faith-based sample in Atlanta, GA. The overall prevalence of DM was 18.3% (22.5% in men and 13.6% in women). Mohanty et al. (2005) compared 555 Asian Indians to 87,846 non-Hispanic whites in the NHIS dataset from 1997 to 2000 and reported that the latter had significantly higher odds of having diabetes. However, they also reported lower CHD and hypertension rates, in contrast to prior studies that showed much higher age-standardized CVD rates and related mortality in this ethnic group. Data from national surveys are limited due to small sample sizes or aggregation of ethnic data into a heterogeneous group of “Asian Americans” or “Asian and Pacific Islanders.” Population-based national studies on prevalence and risk factors for DM and CVD among US Asian Indians are currently lacking.

Asian Indians, the third largest and fastest growing US Asian subgroup, are heterogeneous, with numerous languages, religions, racial types, social habits, cultural practices, and diets. Despite a perception that they have high socio-economic status and good access to health care (Gupta, 2000), US Asian Indians have marked variations in educational attainment, income, and wealth, and a significant number lack education and job skills (Rangaswamy, 1995). Recent immigrant cohorts comprise both highly educated professionals and individuals who lack education and job skills. The latter are mostly family members of earlier immigrants (Rangaswamy, 1995). This heterogeneity makes it imperative to use large, randomized samples to determine disease prevalence and risk factors. Previous studies of Asian Indian health have employed hospital-based or convenience samples (Abate et al., 1995, 1996, 2004; Banerji et al., 1999; Enas et al., 1996; Raji, Seely et al., 2001; Raji, Williams et al., 2001; Venkataraman et al., 2004). The Diabetes among Indian Americans (DIA) study is the first to develop and utilize a large, randomly selected, nationwide cohort of US Asian Indians to determine the prevalence of DM, MetS, and CVD risk factors.

2. Research design and methods

2.1. Subjects

Asian Indian adults were randomly selected at seven US urban sites—Houston, TX; Phoenix, AZ; Washington, DC; Boston, MA; San Diego, CA; Edison, NJ; and Parsippany, NJ. There is no directory/sampling frame available for

Asian Indians in the US; hence directories were created at each site through compilations of several sources: (1) city-wide telephone directories with a search for the 100 most common Asian Indian last names, (2) directories of ethnic associations (e.g., Gujarati Association, Telugu Association), (3) faith-based associations (e.g., temple directories), and (4) professional associations. These sources enabled recruitment of a diverse cross section of subjects. Given the lack of public access to a more complete database of Asian Indians in the United States, this approach to achieve comprehensive representation and random sampling is highly rigorous. Subjects ($n=5000$) were selected from this database ($n=43,120$) using computerized random numbers and were invited to participate by letters and follow-up telephone calls; 30% of the letters were returned due to incomplete address or no forwarding address, and 10% of the phone numbers were disconnected. Inclusion criteria were having both parents from India, age ≥ 18 years, and residence in the US for at least 1 year. Exclusion criteria included self-reported pregnancy status and family members' report of significant mental or psychiatric impairment.

2.2. Data collection

Telephone interviews were completed by trained, multilingual Asian Indian staff. Fasting blood tests and anthropometry were completed at a local community center, clinic, or hospital. Blood samples were drawn after a 10-h fast, coded, immediately centrifuged to separate plasma or serum, and shipped on ice to three core laboratories for biochemical analysis—Atherotech Laboratory (Birmingham, AL, USA), Diabetes Diagnostic Laboratory (Columbia, MO, USA), and the Translational Metabolism Unit, Baylor College of Medicine (Houston, TX, USA). The response rate was 37% ($n=1838$) for the phone interview; of these 56% ($n=1038$) completed the fasting blood work. For respondents who were unwilling to participate in the study, interviewers asked the reasons for nonparticipation as well as demographic information (age, gender, educational level, number of years lived in the US, smoking status, and family history of diabetes and heart disease) for comparison of respondents to nonrespondents. Nonparticipants did not differ in educational level, family history of diabetes and CVD, or smoking status, but were significantly older than participants. The overall response rate was higher than in published health surveys of Asians or Asian Indians (Lien & Van Nuys, 2004; Misra et al., 2000; Misra & Vadaparampil, 2004; Yagalla et al., 1996).

2.3. Measures

Demographic information included age, gender, marital status, education, income, health insurance, place of birth, and duration of US residency. Participants were asked

whether they had a family history of diabetes and chronic diseases among siblings, parents, and grandparents.

2.4. Anthropometry

Height, weight, and waist and hip circumferences were measured by standard procedures. Body mass index (BMI) and waist–hip ratio (WHR) were calculated.

2.5. Fasting glucose and insulin

Fasting capillary glucose was measured using Accucheck Advantage (Roche Diagnostics, Indianapolis, IN, USA). Plasma insulin was measured by radioimmunoassay using the highly specific human insulin kit from Linco Research (St. Louis, MO, USA) at the Translational Metabolism Unit, Baylor College of Medicine, Houston, TX, USA. All samples were assayed in duplicate and the assay repeated if the difference between duplicate results of a sample exceeded 10% coefficient of variation (CV). The mean interassay CV was 5% and intra-assay CVs were less than 8%.

2.6. Risk factors for diabetes and CVD

Plasma samples were assayed for triglycerides, lipoprotein(a), homocysteine, C-reactive protein, total cholesterol, LDL cholesterol, HDL cholesterol, and LDL subclasses using the Vertical Auto Profile test at the Atherotech Laboratory in Birmingham, AL. HbA_{1c} was measured using a Tosoh 2.2 Plus ion-exchange HPLC method at the Diabetes Diagnostic Laboratory in Columbia, MO.

2.7. Metabolic syndrome

MetS was assessed according to three sets of criteria: the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria (Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report, 2002), the modified NCEP ATP III criteria (Grundy et al., 2004), and the International Diabetes Federation (2005) criteria.

2.8. Prevalence of diabetes, obesity, and hypertension

Diabetes was defined by fasting blood glucose ≥ 126 mg/dl or a self-report of previously diagnosed diabetes. Impaired fasting glucose (IFG) was defined by fasting blood glucose values ≥ 100 and ≤ 125 mg/dl. Subjects with no prior diagnosis of diabetes who had fasting blood glucose ≥ 126 mg/dl and HbA_{1c} $< 6.0\%$ were also classified as IFG. Hypertension was defined as blood pressure $\geq 140/90$ mmHg or a self-report of previously diagnosed hypertension. Obesity was assessed by BMI cutoffs using both standard criteria and the World Health Organization

Western Pacific Region (WHO-WPR) (World Health Organization Western Pacific Region, International Association for the Study of Obesity, International Obesity Task Force, 2000).

2.9. Statistics

Rates of discrete variables for age and sex were standardized by use of all participants in the study as the standard population (Berry, Armitage, & Matthews, 1994). Continuous variables are presented as age-adjusted and sex-adjusted means with their standard deviations, unless otherwise specified. ANOVA was used to examine gender and group differences in CVD risk factors. Sample size calculations indicated that 656 participants would provide over 80% power to calculate prevalence rate and detect important differences in CVD risk.

3. Results

3.1. Demographic, dietary, and socioeconomic characteristics

The mean age of the subjects was 45.7 ± 12.8 years (mean \pm S.D.) with a range of 19–91 years. The majority were male (61%), married (91%), employed (58%), and with some form of health insurance (85%). The modal income was \$50,000 to \$100,000; 12% reported income below \$25,000.00. Mean length of residence in the US was 18.5 ± 11.04 years, and 1.6% were born in the US. Fifty-seven percent reported a family history of diabetes and 6.6% were current smokers (predominantly male).

The majority of the subjects were nonvegetarian (60%), reported a change in their food habits (meal times, changes of dietary preference, and increased consumption of fast food) since moving to the US (52%), and 18% practiced some form of dietary restriction for health reasons. More than 50% failed to follow the Food Guide Pyramid recommendations for fruit and vegetable consumption and 65% did not follow the Surgeon General's recommendation for physical activity (30 min a day at least five times a week).

3.2. Obesity

The mean BMI was 25.4 ± 3.7 . Thirty-eight percent were overweight (BMI > 25 but < 30 kg/m²) and 11% were obese (BMI ≥ 30 kg/m²) using standard criteria. With the use of the “Asian” criteria of the WHO-WPR (World Health Organization Western Pacific Region, International Association for the Study of Obesity, International Obesity Task Force, 2000) and the International Association for the Study of Obesity/International Obesity Task Force, 25% were overweight and 49.8% obese. The mean WHR was 0.89 ± 0.1 and was elevated (> 0.90) in 43.8%.

3.3. Prevalence of diabetes and prediabetes

A total of 181 subjects had DM, for a prevalence rate of 17.4%. This included 13.9% with known diabetes and 3.5% with previously undiagnosed diabetes (Table 1). Of these, 112 had FBG ≥ 126 mg/dl at the time of testing, while 69 subjects self-reported diabetes but had FBG ≤ 125 mg/dl. Of these 69 subjects, 38 (55%) reported receiving active treatment with antidiabetic medications. IFG was present in 32.9% of the subjects. The mean fasting blood glucose level for the entire cohort was in the impaired range (111.2 mg/dl for males, 107.4 mg/dl for females). Average glucose values (Consensus Statement on the Worldwide Standardization of the Hemoglobin A_{1c} Measurement, 2007) calculated from the subjects'

Table 1

(a) Prevalence of diabetes			
Diabetes mellitus	Prevalence	Fasting blood glucose (mean \pm S.D.)	HbA _{1c} (mean \pm S.D.)
Prevalence of DM	17.4% (n=181)		
Known diabetes	14.0% (n=145)	137.0 \pm 42.7	6.8 \pm 1.3
Previously undiagnosed diabetes	3.4% (n=36)	156.0 \pm 35.6	7.3 \pm 1.4
Gender			
Males	20.0%	146.0 \pm 46.6 *	6.9 \pm 1.3
Females	13.8%	138.3 \pm 39.5 *	6.9 \pm 1.3
Age groups			
20–39 years	3.9%	125.8 \pm 33.2 *	6.3 \pm 1.5
40–59 years	17.1%	141.8 \pm 44.4 *	7.0 \pm 1.4 *
≥ 60 years	31.2%	145.9 \pm 40.5 *	7.1 \pm 1.1 *
(b) Prevalence of prediabetes			
Prediabetes	Prevalence	Fasting blood glucose	
		Mean	S.D.
	32.9% (n=342)	109.0	7.9
Gender			
Males	36.9%	109.2 *	7.6
Females	27.3%	108.9 *	8.1
Age groups			
20–39 years	31.8%	107.3 *	6.8
40–59 years	37.6%	109.3 *	7.9
≥ 60 years	28.4%	110.6 *	9.1
(c) Glycemic levels in the total cohort			
Total cases	n	Fasting blood glucose	
		Mean	S.D.
All cases	1038		
Gender			
Males	609	111.2 *	26.8
Females	429	107.4 *	27.4
Age groups			
20–39 years	283	99.9 *	14.9
40–59 years	497	111.1 *	27.5
≥ 60 years	215	119.5 *	33.2

* Significant differences between groups assessed by ANOVA; significance defined at $P < .05$.

HbA_{1c} correlated strongly ($r = .77$) with the fasting blood glucose levels. Prevalence of diabetes was significantly higher among individuals who had a first-degree relative with diabetes (11.6%) than among individuals without a family history (5.0%), corresponding to a crude odds ratio of 2.3.

3.4. Prevalence of individual MetS risk factors

The age-adjusted prevalence of MetS was 26.9% by NCEP/ATP III criteria, 32.7% by the modified NCEP/ATP III criteria, and 38.2% by IDF criteria (Table 2). The age-adjusted rate for women (29.1%) was higher than for men (25.3%) using NCEP/ATP III criteria, but similar using the other two criteria. The MetS rates for women increased with age using all three criteria; for men, MetS rates increased only modestly using NCEP/ATP III or IDF criteria (Table 2). The most frequent contributing components of MetS were IFG (62.5%), high triglyceride levels (42.3%), and low HDL-C levels (37.7%). With the use of the NCEP criteria, abdominal obesity was least frequent (22.5%); however, with the use of IDF criteria, the frequency of abdominal obesity increased to 61.2%. There were significant gender differences in four of the five components of MetS (serum triglycerides, blood pressure, cholesterol, and abdominal obesity). Females had a higher frequency of abdominal obesity and low HDL-C levels, while males had a higher frequency of hypertriglyceridemia and hypertension.

3.5. Prevalence of CVD risk factors

There was a high frequency of hypertriglyceridemia (42.3%), increased total cholesterol (43.5%), high LDL-C (41.4%, > 130 mg/dl), low HDL-C (26.4%), elevated C-reactive protein (65%), and homocysteine (40.5%) (Table 3). A high frequency of elevated lipoprotein(a) was not observed. Significant gender differences existed for eight of the 11 measured risk factors. Females had higher rates of increased total cholesterol, C-reactive protein, and lipoprotein(a), while males had higher rates of low HDL-C, hypertriglyceridemia, hyperhomocysteinemia, and elevated fasting glucose.

The highest rates of general and abdominal obesity, hypertriglyceridemia, hyperhomocysteinemia, elevated C-reactive protein, increased systolic and diastolic blood pressure, and low HDL-C were observed among diabetic subjects, compared to normoglycemic and IFG subjects. Pearson's correlation indicated significant associations between fasting blood glucose levels and waist circumference ($r = 0.286$; $P < .01$), hip circumference ($r = 0.192$), WHR ($r = 0.159$), BMI ($r = 0.256$), serum triglycerides ($r = 0.218$), homocysteine ($r = 0.107$), insulin resistance ($r = 0.421$), fasting insulin ($r = 0.210$), HDL-C ($r = -0.163$), and LDL-C ($r = 0.108$). Strong positive correlations were also noted

Table 2

(a) Prevalence of metabolic syndrome

	<i>n</i>	Original NCEP/ ATP III definition	Modified NCEP/ ATPIII definition	IDF Definition
Total				
Unadjusted	997	26.7 (0.44)	32.4 (0.47)	37.6 (.48)
Age adjusted	997	26.9 (0.44)	32.7 (0.47)	38.17 (.48)
Men				
Total				
Unadjusted	582	25.3 (0.43)	32.7 (0.46)	37.87 (.49)
Age adjusted	582	25.3 (0.43)	33.1 (0.47)	38.47 (.48)
20–39 years	164	21.3 (0.41) (ns)	32.9 (0.47) (ns)	29.5 (.46)*
40–59 years	279	26.5 (0.44) (ns)	33.3 (0.47) (ns)	38.4 (.48)*
≥60 years	139	28.1 (0.45) (ns)	33.1 (0.47) (ns)	49.3 (.50)*
Women				
Total				
Unadjusted	413	28.7 (0.45)	31.9 (0.46)	37.3 (.48)
Age adjusted	413	29.1 (0.45)	32.2 (0.47)	37.7 (.48)
20–39 years	119	15.9 (0.37)*	18.5 (0.39)*	23.5 (.42)*
40–59 years	218	29.8 (0.46)*	33.5 (0.47)*	42.0 (.49)*
≥60 years	76	47.4 (0.50)*	50.0 (0.50)*	48.0 (.50)*

Data are presented as percent (S.D.); * $P < .05$, ns=not significant.

(b) Age-adjusted prevalence of individual metabolic syndrome factors

	<i>n</i>	Abdominal obesity		High serum triglyceride	Low HDL cholesterol	High blood pressure or medication use	High fasting glucose (≥110 mg/dl) or medication use	High fasting glucose (≥100 mg/dl) or medication use
		≥102 cm (M) ≥88 cm (W)	≥90 cm (M) ≥80 cm (W)					
Total	1038	22.5 (.42)	61.2 (.48)	42.3 (.49)	37.7 (.48)	35.6 (.47)	37.3 (.48)	62.7 (.48)
Men*	609	12.8 (.33)	56.4 (.49)	48.6 (.50)	34.5 (.47)	38.3 (.48)	40.4 (.49)	68.5 (.46)
Women*	429	36.3 (.48)	68.0 (.46)	33.5 (.47)	42.3 (.49)	31.5 (.46)	32.9 (.47)	54.5 (.49)

Data are presented as percent (S.D.); * $P < .05$, ns=not significant.

between fasting blood glucose, fasting insulin, HOMA-IR, and HOMA-B.

4. Discussion

These results from the first randomly selected, population-based study of Asian Indians in the US indicate a very high prevalence of diabetes, prediabetes, and MetS. The prevalence of DM for adults aged ≥20 years (17.4%) exceeds that of non-Hispanic whites (NHW) (7.8%), non-Hispanic blacks (13%), Hispanic Latinos (10.2%), and Native Americans/Alaskan natives (15.1%) as reported by the American Diabetes Association and Centers for Disease Control in 2001 (Fig. 1A). The gender disparity in DM prevalence (20% males and 13.8% females) is unusual; it has not been observed in other ethnic groups in large, randomized surveys such as NHANES III (CDC; Annis et al., 2005; Harris et al., 1998; Ramachandran et al., 2001), nor in India (Ramachandran et al., 2001).

The prevalence of MetS among Asian Indian males is higher than that reported among African Americans but similar to non-Hispanic whites and Mexican Americans; among Asian Indian females it is higher than in non-

Hispanic whites and African Americans but lower than Mexican Americans (Fig. 1B) (Ford et al., 2002). The prevalence of MetS does not increase with age among Asian Indian males as it does among Asian Indian females and in other ethnic groups (Ford, 2005; Ford et al., 2004). This suggests that the dysmetabolic state peaks at an early age in Asian Indian males, indicating a need for early prevention strategies in this population.

Elevated fasting blood glucose (62.7%) and hypertriglyceridemia (42.3%) are the most prevalent MetS components, while abdominal obesity is the least frequent MetS criterion. The frequency of IFG is more than twice that reported for Mexican Americans, African Americans, and whites (Ford et al., 2002). The prevalence of hyperglycemia, revealed by the very high rates of DM and prediabetes and of IFG as a component of the MetS, is striking. Furthermore, the mean population fasting blood glucose level (111.2 mg/dl in males and 107.6 mg/dl in females) is much higher than in the general US population (Wu et al., 2002). Hyperglycemia appears to be the driving force for the development of MetS in Asian Indians to a much greater extent than in other US ethnic groups. Dysregulation of fasting glucose metabolism is particularly deranged as compared to the other features of MetS. The high mean fasting glucose levels suggest that

Table 3
CVD Risk factors by gender and fasting blood glucose category

Variables	Male (n=609)	Female (n=429)	P value*	Normal (n=515)	Impaired (n=342)	Diabetic (n=181)	P value*
Total cholesterol	193.7 (34.2)	196.5 (38.3)	.24	194.5 (37.0)	199.6 (34.9)	186.9 (33.7)	.01
HDL Cholesterol	44.5 (10.1)	52.8 (12.6)	.001	49.9 (12.8)	47.4 (11.3)	43.5 (10.1)	<.01
Non-HDL cholesterol	149.1 (33.4)	142.7 (32.5)	.003	143.6 (32.6)	152.2 (33.7)	143.8 (32.6)	.01
Triglycerides	160.9 (77.7)	138.7 (65.4)	.001	140.8 (70.2)	155.1 (69.9)	176.6 (83.4)	<.01
C-Reactive protein	2.43 (5.5)	3.57 (4.9)	.001	2.91 (6.2)	2.53 (3.9)	3.57 (4.7)	.13
Lipoprotein(a)-C [†]	5.75 (3.77)	6.95 (3.83)	.001	6.59 (3.6)	6.17 (4.1)	5.44 (3.9)	.01
Homocysteine	12.7 (6.3)	10.1 (4.0)	.001	11.35 (6.2)	11.58 (4.9)	12.66 (5.0)	.03
Systolic BP	127.1 (18.5)	123.6 (23.0)	.013	23.33 (21.3)	125.2 (18.7)	133.3 (20.6)	<.01
Diastolic BP	78.7 (9.8)	76.2 (11.6)	.001	76.6 (10.4)	78.91 (10.5)	78.55 (11.3)	.01
Waist circumference	35.95 (3.54)	33.4 (4.0)	.001	34.02 (3.8)	35.14 (3.5)	37.04 (4.3)	<.01
Hip	39.2 (3.4)	39.9 (3.9)	.002	39.1 (3.4)	39.5 (3.4)	40.8 (4.3)	<.01
WHR	.91 (.07)	.84 (.07)	.001	.87 (.08)	.89 (.08)	.91 (.09)	<.01
BMI	25.3 (3.3)	25.6 (4.4)	.160	24.61 (3.9)	25.14 (3.5)	26.72 (4.2)	<.01
Fasting blood glucose	111.2 (26.7)	107.4 (27.4)	.01	99.33 (19.8)	109.00 (7.9)	141.08 (41.7)	<.01
Fasting insulin [†]	11.95 (6.4)	11.86 (11.8)	.94	10.02 (5.2)	11.63 (6.9)	16.43 (14.6)	<.01
HOMA B [†]	95.7 (125.9)	89.7 (88.4)	.062	100.2 (83.4)	73.9 (67.1)	113.7 (198.8)	.053
HOMA IR [†]	3.26 (2.21)	3.20 (3.99)	.87	2.33 (1.2)	3.05 (2.0)	5.53 (0.65)	<.01

Values are shown as mean (S.D.).

* Significant difference between normal, impaired, and diabetic groups based on Student *t* test/ANOVA.

[†] Analysis in a subsample of respondents.

dysregulated endogenous glucose production may be a dominant defect in Asian Indians, with possible defects in beta or alpha cell function as well.

Fasting blood glucose levels correlated strongly with waist circumference and WHR and less significantly with BMI, despite a low prevalence of abdominal obesity as defined by the modified NCEP criteria. This suggests that the currently accepted cutoffs for waist circumference as a surrogate for abdominal obesity and its inimical metabolic consequences are inadequate to describe the contribution of this metabolic risk factor in Asian Indians. Furthermore, it supports the concept of a pathophysiologic link between abdominal obesity, insulin resistance, and hyperglycemia in this population.

There was a progressive step-up in metabolic abnormalities between normal, IFG, and DM groups, suggesting that although Asian Indians overall have a higher risk for DM and CVD than many other ethnic groups, they may progress through the stages of dysmetabolism to frank diabetes in a similar manner, with increasing abdominal obesity and BMI. Interestingly, only waist circumference but not hip circumference increased across the categories of glucose tolerance, suggesting that the increased waist–hip ratio is driven particularly by increasing waist circumference, i.e., abdominal obesity, without a concomitant decrease in peripheral or femorogluteal fat.

The lower LDL-C level among diabetic than among IFG subjects could be due to greater use of lipid-lowering drugs or a diabetic diet in those with established diabetes (drug information was not systematically collected as participants did not know or were unsure of medications they were currently using). However, it is also possible that the quantitative change could be due in part to a decrease in LDL particle size as well as to increased CETP activity

resulting in lower LDL cholesterol content. Studies are ongoing to determine whether LDL particle size and CETP activity change in the transition from IFG to diabetes in this population.

The Asian Indian population in the US is relatively young, and the poor health perceptions and behaviors may result from a lack of emphasis on health promotion behaviors in their formative years, stress to establish careers, or not prioritizing wellness behaviors and check-ups (Lip, Luscombe, McCarr, Malik, & Beevers, 1996). There is a need for early and culturally appropriate intervention (especially among men) with educational and lifestyle changes (diet and physical activity) and possibly pharmacotherapy (Chiasson et al., 2005) to prevent diabetes and CVD. Given their genetic, ethnic, and cultural diversity, broad objectives for Asian Americans or Asian Pacific Islanders may not effectively address unique needs of Asian Indians.

The limitations of this study include self-reported data and single capillary glucose values with no oral glucose tolerance tests for assessing prevalence of diabetes and impaired glucose levels. However, field-based studies such as the REDIA Study (Favier et al., 2005) have used capillary blood glucose measurements; studies have reported a very high correlation ($r=0.95$ and 0.96) between capillary glucose and plasma glucose (Godine et al., 1986; Lewandrowski et al., 1992). Since the prevalence of diabetes is usually underestimated by fasting glucose testing compared to oral glucose tolerance testing, it is possible that the actual prevalence of diabetes among US Asian Indians is even higher than we report here. Although this the first truly randomly selected health survey of Asian Indians in the US, the response rate for current study was relatively low, i.e., 37% for phone interview and 20% with complete survey and clinical data. Since no study on Asian Indians has used a

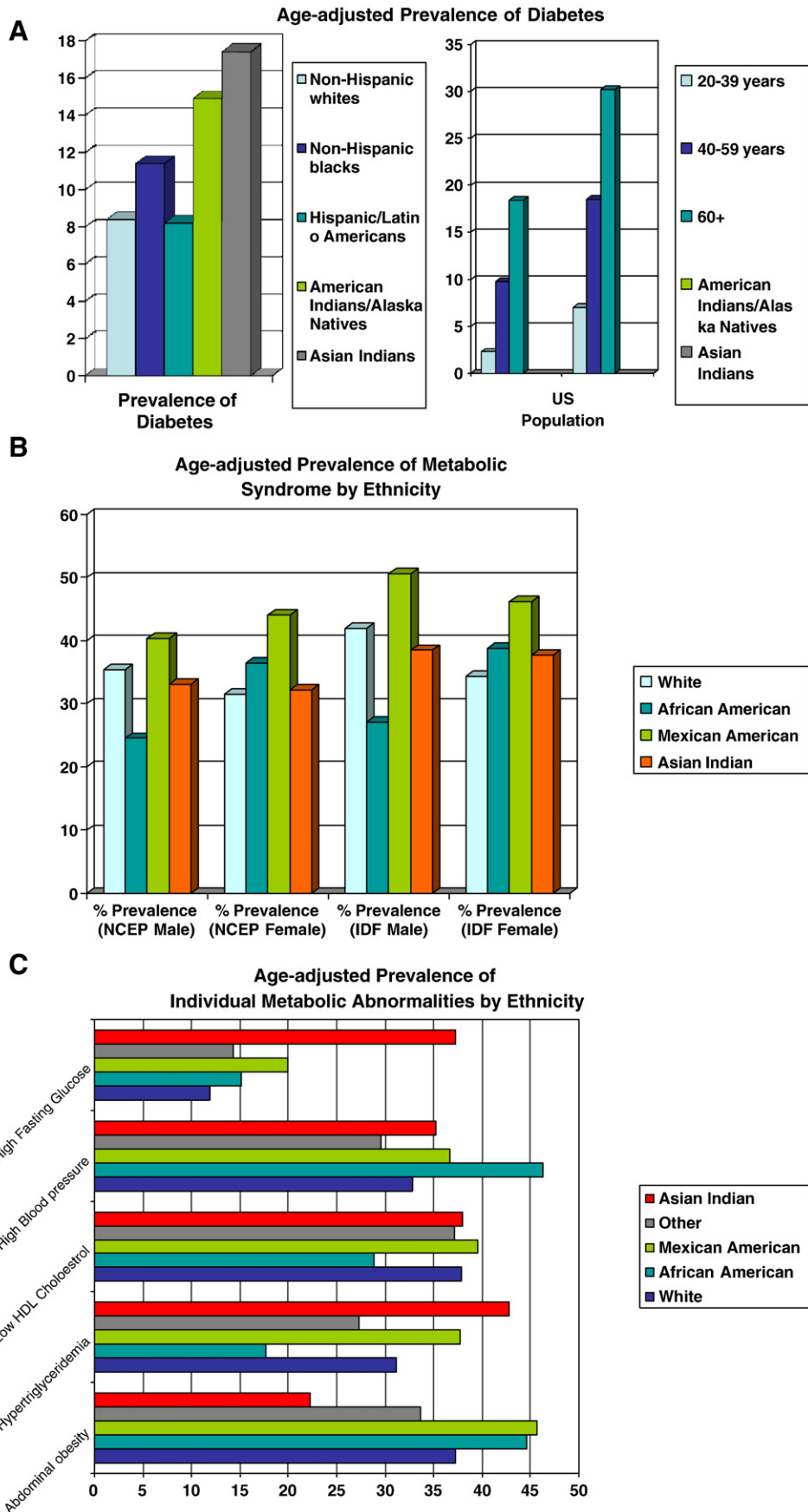


Fig. 1. Prevalence of diabetes and metabolic syndrome: comparison of Asian Indians to other racial/ethnic groups.

random sample such as the DIA study, response rates have never been reported for this population for survey/clinical assessments. A low response could be associated with selection bias in that people with known diabetes might be more likely to respond to a study about diabetes. This may also explain the relatively low rate of previously undiagnosed diabetes in this study. However, our response rate compares very well with those for national surveys of Asian Americans, e.g., 21% among Chinese Americans and 24% among Korean Americans (Lee & Cheng, 2006). Previous large-scale surveys of Asian Indians have had a lower or similar response rate (Misra et al., 2000; Misra & Vadapampil, 2004) in the face of intensive recruitment efforts. It is possible that these are optimal response rates for these ethnic groups within the US.

In conclusion, Asian Indians in the US have a strong predisposition for diabetes and heart disease. This, coupled with physical inactivity, abdominal obesity, and Westernized lifestyle after immigration, could contribute to early onset of chronic diseases. The results indicate a very high prevalence of DM and MetS among Asian Indians—one of the highest among US ethnic groups—with progressive worsening of all metabolic parameters in the spectrum from normoglycemic to IFG to DM. These data provide a firm basis for future mechanistic and interventional studies in this rapidly growing segment of the US population.

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