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## Is the “South Asian Phenotype” Unique to South Asians? Comparing Cardiometabolic Risk Factors in the CARRS and NHANES studies

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### Abstract

**Background**—In the context of rising obesity in South Asia, it is unclear whether the “South Asian phenotype”—described as high glucose, low high density lipoprotein cholesterol (HDL) and high triglycerides at normal ranges of body mass index (BMI)—continues to be disproportionately exhibited by contemporary South Asians relative to other race/ethnic groups.

**Aim**—We assessed the distinctiveness of the South Asian cardiometabolic profile by comparing the prevalence of combined high glucose, high triglycerides, and low HDL (“combined dysglycemia and dyslipidemia”) in resident South Asians with four race/ethnic groups in the United States (US): Asians, Blacks, Hispanics, and Whites overall and by BMI category.

**Methods**—South Asian data were from the 2010–11 Center for cArdiometabolic Risk Reduction in South Asia Study, representative of Chennai and New Delhi, India and Karachi, Pakistan. United States data were from the 2011–2012 National Health and Nutrition Examination Survey, representative of the US population. Combined dysglycemia and dyslipidemia was defined as fasting blood glucose  $\geq 126$  mg/dL and triglyceride:HDL ratio  $>4$ . Logistic regression was used to estimate the relative odds (OR) and 95% CIs of combined dysglycemia and dyslipidemia associated with each race/ethnic group (ref=US Whites). Models were estimated among adults aged 20–79 years by sex and BMI category and accounted for age, education, and tobacco use.

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**Results**—Data from 8,448 resident South Asians, 274 US Asians, 404 US Blacks, 308 US Hispanics, and 703 US Whites without previously known diabetes were analyzed. In the normal BMI range of 18.5 to 24.9 kg/m<sup>2</sup>, the prevalence of combined dysglycemia and dyslipidemia among men and women, respectively, was 33% and 11% in resident South Asians, 15% and 1% in US Asians, 5% and 2% in US Blacks, 11% and 2% in US Hispanics, and 8% and 2% in US Whites. Compared with US Whites, South Asians were more likely to present with combined dysglycemia and dyslipidemia at all categories of BMI for men and at BMI 18.5 to 29.9 for women in adjusted models. The most pronounced difference between South Asians and US Whites was observed at normal weight (adjusted odds ratio [aOR]= 4.98; 2.46–10.07 for men and aOR=9.09; 2.48–33.29 for women).

**Conclusions**—Between 8% to 15% of US men and 1% to 2% of US women of diverse race/ethnic backgrounds exhibited dysglycemia and dyslipidemia at levels of BMI considered “healthy,” consistent with the cardiometabolic profile described as the “South Asian Phenotype.” Urban South Asians, however, were 5 to 9 times more likely to exhibit dysglycemia and dyslipidemia in the “healthy” BMI range compared with any other US race/ethnic group.

## INTRODUCTION

South Asians, or people who trace their ancestry to the Indian subcontinent, have been observed to exhibit higher indicators of cardiometabolic risk relative to White populations despite lower body mass index; this has been termed the “South Asian” or “Asian Indian phenotype” [1,2]. Among the consistently noted distinctive features of this phenotype are abdominal adiposity combined with glucose intolerance and specific dyslipidemias—such as low levels of high-density lipoprotein cholesterol (HDL), high levels of triglycerides and low-density lipoprotein (LDL), and high triglycerides relative to HDL—at levels of overall body mass considered normal in other populations [1–3]. Authors have also variously described additional features such as excess body fat per unit BMI, truncal subcutaneous fat, higher c-reactive protein, and lower adiponectin as part of the South Asian phenotypic package; others have equated the South Asian phenotype with metabolic syndrome [1–3]. The South Asian phenotype has been invoked to explain, in part, reports of elevated coronary heart disease, events, and cardiovascular mortality among migrant South Asians relative to local populations in diverse settings that date back several decades [4–8].

Although cardiometabolic risk associated with South Asian race/ethnicity may reflect any combination of common environmental exposures and stressors, genetic predisposition, shared behaviors, or similar social circumstances in migrant settings, long-term undernutrition at the population level is a leading hypothesis for the phenotype. Specifically, researchers posit that early life undernutrition (reflected in low birth weight and poor early life growth) predisposes South Asians to elevated metabolic risk later in life in this population [9–13]. Recently observed transitions from undernutrition to overnutrition, however, appear to be altering the low average weight status traditionally associated with South Asians. For example, the most recent national data indicated that overweight and obesity increased (and underweight decreased) from 1996 to 2006 among women in multiple South Asian countries [14], and the prevalence of overweight was higher than that of underweight among middle-aged urban adults in India [15]. Similarly, recent studies in

India have also indicated that overweight exceeded underweight in urban adolescents in industrial settings [16]

In light of rising trend towards excess weight in urban populations in South Asian, we assessed the distinctiveness of contemporary urban South Asians with respect to their cardiometabolic phenotype. Specifically, we compared the prevalence of combined high fasting plasma glucose and high triglycerides relative to HDL among resident South Asians with prevalence of this combination in four race/ethnic groups residing in the United States (US), Asians, Blacks, Hispanics, and Whites, at varying levels of BMI. We focused on high glucose and high triglycerides relative to HDL because glucose intolerance and accompanying specific dyslipidemias are the hallmark of the South Asian phenotype [1,3]. We also sought to add to the literature by comparing South Asians with multiple race/ethnic groups because race/ethnic classifications are an imperfect yet pragmatic way to group people who may have common historical nutritional and social experiences relevant to their cardiometabolic phenotype [17–19].

## **METHODS**

### **Participants and data sources**

Data for this study were from two large population-based, representative samples: the 2010–2011 assessment of the Center for cArdiometabolic Risk Reduction in South Asia Study (CARRS) and 2011–2012 National Health and Nutrition Examination Survey (NHANES). CARRS is an ongoing cohort study designed to be representative of non-pregnant adults aged 20 years and older residing in Chennai and New Delhi, India and Karachi, Pakistan in 2010–2011. NHANES is a biennial cross-sectional study designed to be representative of the United States population. Details of both studies are published [20,21]. We restricted the current analysis to adults aged 20–79 years in demographic groups of interest without a prior diagnosis of diabetes (self-reported), with complete anthropometric (height, weight) and laboratory assessments (fasting plasma glucose, triglycerides, HDL), and BMI>18.5. A total of 8448 participants from CARRS and 1,789 participants from NHANES matched these criteria and were included in the study sample. Figure 1 shows a flow diagram of the inclusion/exclusion criteria that produced the analytic sample.

### **Residential and race/ethnic classification**

We categorized the sample into 5 mutually exclusive demographic groups based on residence and race/ethnicity. All participants from CARRS were classified as “resident South Asians.” In NHANES, race/ethnicity was self-reported and our sample was categorized into four groups: 1) US Asians; 2) US Blacks; 3) US Hispanics; and 4) US Whites. All NHANES participants beyond these categories were excluded from analysis. The US Asian group is composed of both East Asians and South Asians, and the publicly available NHANES data do not allow for distinguishing between these two groups.

### **Body mass index classification**

We followed the international classification of body mass index (BMI). BMI<18.5 was excluded. BMI ranging from 18.5 to 24.9 kg/m<sup>2</sup> was considered “normal weight;” BMI

ranging from 25 to 30 was considered “overweight;” and BMI>30 was considered “obese.” These three categories, normal weight, overweight, and obese, were employed in the primary analysis.

### Combined dysglycemia and dyslipidemia

We defined combined dysglycemia and dyslipidemia as the presence of fasting plasma glucose (FPG)  $\geq 126$  mg/dL and triglyceride to high-density lipoprotein cholesterol (HDL) ratio  $> 4$ . When this package of high glucose and dyslipidemias is present at normal BMI, it reflects the “South Asian” phenotype.

In the CARRS study, fasting blood samples were collected in the morning (minimum eight hours of fasting) at local camps when possible or in the home of participants. Samples were sent to an accredited laboratory in the respective city of data collection (Chennai, New Delhi, or Karachi) for analysis on the same day as they were collected. All three laboratories used by CARRS participated in a Randox International Quality Assessment Scheme (RIQAS) that standardized findings to a central laboratory at the Public Health Foundation of India/Centre for Chronic Disease Control in New Delhi. In the NHANES study, blood samples were collected at mobile examination centers; only participants who were examined in the morning were eligible for blood glucose and triglycerides assessment, and only those fasting for nine hours or more were assigned positive analytic weights. NHANES samples were analyzed at the University of Minnesota; vials were stored at  $-20$  degrees C for shipment. Both CARRS and NHANES used standardized laboratory protocols for the assessment of plasma glucose (hexokinase/kinetic method), triglycerides (enzymatically with glycerol blanking in NHANES only), and HDL (the direct method).

### Statistical analysis

Survey weights were used to age-standardize each group to the WHO standard population structure in descriptive analysis [22]. Analyses described the prevalence of combined dysglycemia and dyslipidemia by ethnicity-residence group for each sex and BMI category separately. Within each sex-BMI category, differences in prevalence relative to resident South Asians were estimated using a binomial model with robust variance estimation [23]. Logistic regression was used to compute the odds (and 95% confidence intervals) of combined dysglycemia and dyslipidemia for each race/ethnic group relative to US Whites. US Whites, instead of resident South Asians, were used as the referent in the logistic models because US Whites were the largest US group for comparison and the magnitudes of odds ratio estimates were expected to mostly be in the positive direction. Adjusted logistic regression models accounted for age, college education, and tobacco use.

In addition, we conducted two sensitivity analyses. First, we specified an alternate definition of the cardiometabolic package, and analyzed differences in the “metabolic syndrome” defined per the 2009 American Heart Association Harmonization Panel [24]. This definition considers any 3 of 5 risk factors as the criterion for metabolic syndrome: high waist circumference (ethnic definitions, see [24]); triglycerides  $\geq 150$  mg/dl; systolic blood pressure  $\geq 130$  or diastolic blood pressure  $\geq 85$  mmHg or hypertension medication; FPG  $\geq 100$  mg/dl or medication; HDL  $< 40$  mg/dl. Participants with diabetes were not excluded from the

metabolic syndrome analysis because diabetes medication is part of the definition of metabolic syndrome. Second, we specified alternate weight classification categories by using thresholds recommended for Asians (BMI 18.5–22.9 kg/m<sup>2</sup> as normal, 23–24.9 kg/m<sup>2</sup> as overweight, and 25 kg/m<sup>2</sup> or above as obese).

### Ethics approval

The CARRS study protocol was approved by ethics committees of the Public Health Foundation of India and AIIMS (Delhi), Madras Diabetes Research Foundation (Chennai), Aga Khan University (Karachi) and Emory University (Atlanta). The NHANES 2011–12 study protocol was approved by the National Center for Health Statistics Ethics Review Board (Protocol #2011-17).

## RESULTS

Table 1 describes participant characteristics by race/ethnic group and sex. Data from 8,448 resident South Asians, 274 US Asians, 404 US Blacks, 308 US Hispanics, and 703 US Whites without prior diabetes diagnosis were included in the analytic sample. The mean age of participants in each race/ethnic group, after age-standardization, ranged from 35 to 41 years among men and 37 to 42 years among women. The proportion of college graduates was smallest in resident South Asians and largest in US Asians. Tobacco use was highest in South Asians (40%) among men and in US Whites (18%) among women. Mean BMI was highest in US Hispanics (28.89±0.43 kg/m<sup>2</sup>) among men and in US Blacks (31.53±0.60 kg/m<sup>2</sup>) among women. Notably, South Asian men had BMI comparable to US Asian men (24.84 vs 24.86 kg/m<sup>2</sup>, respectively) and South Asian women had significantly higher BMI than US Asian women (26.84 vs 23.53 kg/m<sup>2</sup>, respectively); BMI among South and US Asians was lower than that of any other group.

Figure 2 (and Appendix Table 1) shows the prevalence of combined dysglycemia and dyslipidemia, defined as FPG ≥126 and triglyceride:HDL ratio>4, by demographic group. Combining all BMI categories, South Asians had the highest prevalence, 41% and 20% in men and women respectively. In the normal BMI range of 18.5 to 24.9 kg/m<sup>2</sup>, prevalence was 33% and 11% in resident South Asian, 15% and 1% in US Asian, 5% and 2% in US Blacks, 11% and 2% in US Hispanics, and 8% and 2% in US White men and women, respectively. Compared with South Asian men, the prevalence of combined dysglycemia and dyslipidemia was statistically significantly lower in US Black, Hispanic, and White men at all BMI levels; prevalence in US Asian men was significantly different in the normal (BMI 25.0 to 29.9 kg/m<sup>2</sup>) and overweight range (30.0 and above kg/m<sup>2</sup>). Compared with South Asian women, the prevalence of combined dysglycemia and dyslipidemia was statistically significantly lower among US Asian, Black, Hispanic, and White women at all BMI levels with the exception of Asian women in the overweight and obese range and Hispanic women in the obese range. Across weight categories, combined dysglycemia and dyslipidemia tended to be lowest in the normal weight group (ranges: 5% to 33% among men and 1% to 2% among women) and highest in the obese group (ranges: 15% to 53% among men and 10% to 30% among women). The prevalence of combined dysglycemia and dyslipidemia

was lower among women compared with men in each BMI category for all race/ethnic groups.

Figure 3 (and Appendix Table 2) shows the relative odds of combined dysglycemia and dyslipidemia associated with race/ethnic group (ref=US Whites) overall and by BMI levels. Compared with US Whites, adjusted relative odds (aOR; 95% confidence intervals) of combined dysglycemia and dyslipidemia were aOR=1.94 (1.48–2.54) and aOR=2.55 (1.53–4.27) for South Asian men and women, respectively. At each BMI level, with the exception of obese women, South Asian ethnicity was associated with the highest adjusted relative odds of combined dysglycemia and dyslipidemia. Comparing South Asians with US Whites, odds ratios tended to be largest in the normal BMI range and smallest in the obese range. Normal weight South Asian men were nearly five times as likely to have combined dysglycemia and dyslipidemia as normal weight US White men (aOR=4.98; 2.46–10.07). South Asian women had greater odds of combined dysglycemia and dyslipidemia compared with US women in the normal (aOR=9.09; 2.48–33.29) and overweight (aOR=3.14; 1.34–7.36), but not obese, BMI range. With the exception of US Black men (OR=0.30; 0.16–0.60), no other US group statistically differed from US Whites with respect to combined dysglycemia and dyslipidemia in the overall sample. In analyses stratified by BMI, relative to US Whites, Black men had lesser odds of combined dysglycemia and dyslipidemia in the overweight and obese range, Black women had lesser odds in the obese range, and Hispanic women had lesser odds in the overweight range.

Appendix Tables 1 and 2 show the sensitivity analysis examining metabolic syndrome by BMI levels and race/ethnicity. The prevalence of metabolic syndrome was between 1.5 to 5 times higher than that of combined dysglycemia and dyslipidemia in US Black, Hispanic and White men and in women of all race/ethnic groups (Appendix Table 1). The adjusted relative odds of metabolic syndrome was higher among South Asians compared with US Whites at all levels of BMI; associations were attenuated compared with those observed for combined dysglycemia and dyslipidemia. Appendix Table 3 shows the sensitivity analysis examining combined dysglycemia and dyslipidemia within BMI categories suggested for Asians. South Asians had the highest prevalence of combined dysglycemia and dyslipidemia in all categories of BMI defined using Asian-specific thresholds.

## DISCUSSION

Between 11% to 15% of US men and 1% to 2% of US women of varying race/ethnic backgrounds exhibited combined dysglycemia and dyslipidemia at levels of BMI considered healthy (i.e., “normal” BMI range of 18.5–24.9), consistent with the cardiometabolic profile described as the “South Asian Phenotype.” Urban South Asians, however, were 5 to 9 times more likely to exhibit this combination at normal weight compared with any other US race/ethnic group. These findings, based on recent population-based data of multiple race/ethnic groups, are consistent with a large body of literature reporting that South Asians tend to experience worse cardiometabolic health despite lower body mass index levels compared with other ethnic groups [25–27].

Although combined dysglycemia and dyslipidemia was more common among normal weight South Asian individuals than normal weight individuals from other groups, 5% to 15% of US men with normal weight had this metabolic package. A separate literature has described a phenotype described as “metabolically obese but normal weight” [28–32]. Higher percent body fat and lower fat-free mass has been noted among metabolically obese but normal weight individuals [28], and in keeping with this, higher metabolic abnormalities have been observed among normal weight people with higher body fat content [33]. The metabolic obese but normal weight phenotype has been examined among migrant and resident South Asians, using definitions of metabolic syndrome that included hypertension [34,35]. Whether there is a causal convergence between the so-called “metabolically obese but normal weight” and “South Asian” phenotypes [34] would be an interesting topic of future research and possibly important to identify individuals with adverse cardiometabolic profiles who are otherwise considered low risk based on anthropometric screening.

This study was motivated in part by the hypothesis that the nutrition transition from undernutrition to overweight may be reducing differences between South Asians and other populations with respect to cardiometabolic risk profile. Our results suggest that, to the contrary, South Asians continue to exhibit specific glucose-associated dyslipidemias at levels disproportionate to other groups. One possible explanation for the findings is continued suboptimal early life nutrition. The prevalence of low birth weight has been slow to decline in India—going from 25% in 1992–93 to 21% in 2005–06 [36]. In fact, persistent low birth weight coupled with overweight/obesity later in life would be expected to further increase the prevalence of the thin-fat body type, which has been implicated in the South Asian phenotype [37]. Future studies tracking the weight status of South Asian populations across the lifecourse may be informative to assess whether the high distribution of this phenotype in South Asians is indeed driven by poor early life nutrition.

We recognize that the race/ethnic groupings examined did not capture the vast heterogeneity within each race/ethnic group. Over 60 ethnic groups are represented among Asian Americans alone [38], and we were unable to distinguish between NHANES participants who originated from South Asia and those who originated from other regions of Asia (e.g., Chinese Americans). Because South and East Asians differ with respect to ethnic ancestry, it is important to acknowledge that observed differences between South Asians in CARRS and all Asians in NHANES may be due to a combination of hereditary, environmental, and/or cultural/behavioral factors that are observed to cluster within race/ethnic groupings.

Among the limitations of this study is the lack of a universal definition of the distinctive metabolic risk profile attributed to South Asians. For example, abdominal adiposity is often described as part of the South Asian phenotype, and we did not include abdominal adiposity in our primary analysis. We, however, applied a second definition in our sensitivity analysis. Using metabolic syndrome as the outcome, we still observed that South Asians were more likely to have worse metabolic health than US Whites at normal weight. This is reassuring that the ethnic differences reported here are robust to alternate specifications of metabolic risk, including a definition that incorporated abdominal adiposity and hypertension. Further investigation may benefit from examining measures of cardiometabolic risk (FPG, triglycerides, HDL, hypertension) separately to better understand differences by race/ethnic

groups. Another major limitation was the possible lack of power to detect meaningful differences because laboratory data required for our outcome were available for only a small sample of NHANES participants.

We sought to investigate the distinctiveness of the South Asian cardiometabolic phenotype by describing cardiometabolic risk by BMI classification for five groups defined by contrasting race/ethnic and residential characteristics: Resident South Asians, US Asians, US Hispanics, US Blacks, and US Whites. In doing so, the study had several strengths. We combined two recent, large population-based datasets with fairly comprehensive anthropometric and metabolic assessments to shed light on cardiometabolic health in resident South Asians and US populations of diverse race/ethnic background. Participants were assessed close in calendar time, diminishing concerns regarding differences due to secular changes in cardiometabolic health. We included multiple race/ethnic comparison groups residing in the US. Future investigation may fruitfully pool prospective data from multiple sources in an effort to disentangle the modifiable causes of observed differences between resident South Asians and US groups to better guide intervention efforts.

## Acknowledgments

### FUNDING

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## Appendix

**Appendix Table 1**

Prevalence (95%CI) of combined dysglycemia and dyslipidemia by demographic group within BMI category

Sex	Demographic group	Total BMI 18.5–30+	Normal weight BMI 18.5–25	Overweight BMI 25–30	Obese BMI 30+
		Combined dysglycemia and dyslipidemia (FPG 126 & TG:HDL>4)			
Men	Resident South Asians	41.0 (39.3,42.7)	32.9 (30.2,35.6)	50.6 (47.6,53.7)	53.1 (48.0,58.1)
	US Asians	25.3 (16.3,34.3)	15.0 (6.0,24.0)	36.0 (22.1,49.8)	51.5 (22.1,80.9)
	US Blacks	9.5 (3.9,15.1)	5.3 (–1.7,12.4)	8.6 (–1.1,18.3)	14.7 (3.3,26.2)
	US Hispanics	27.0 (21.8,32.2)	10.7 (–0.5,22.0)	31.5 (21.9,41.0)	32.3 (24.2,40.3)
	US Whites	25.7 (21.3,30.2)	8.2 (2.0,14.3)	27.7 (17.4,38.1)	37.9 (28.5,47.3)
Women	Resident South Asians	20.2 (18.8,21.7)	11.4 (9.7,13.0)	23.3 (20.8,25.8)	29.3 (26.1,32.6)
	US Asians	7.7 (3.7,11.8)	1.3 (–0.7,3.3)	22.1 (11.5,32.7)	30.3 (2.1,58.5)
	US Blacks	5.8 (2.7,8.9)	1.6 (–1.5,4.6)	1.5 (–1.5,4.5)	9.6 (4.6,14.6)
	US Hispanics	10.1 (5.4,14.8)	1.6 (–0.5,3.6)	3.3 (–0.2,6.9)	21.6 (11.0,32.2)
	US Whites	10.5 (5.5,15.5)	2.4 (–0.3,5.1)	8.5 (1.9,15.2)	22.5 (10.7,34.3)
			Metabolic syndrome *		



Sex	Demographic group	Total BMI 18.5–30+	Normal weight BMI 18.5–25	Overweight BMI 25–30	Obese BMI 30+
Men	Resident South Asians	47.4 (45.5,49.3)	31.8 (29.6,34.0)	66.4 (63.5,69.3)	80.0 (76.6,83.4)
	US Asians	41.5 (29.0,54.0)	16.2 (4.8,27.7)	61.7 (48.0,75.4)	69.4 (43.0,95.9)
	US Blacks	28.1 (19.9,36.4)	10.4 (0.8,20.0)	11.6 (6.0,17.2)	53.3 (38.0,68.6)
	US Hispanics	47.9 (40.7,55.2)	5.0 (–6.1,16.1)	44.3 (35.4,53.3)	61.8 (55.6,68.0)
	US Whites	48.7 (43.3,54.1)	11.7 (3.0,20.4)	45.1 (36.6,53.5)	67.2 (57.9,76.5)
Women	Resident South Asians	42.0 (39.9,44.1)	23.7 (20.7,26.7)	44.6 (41.3,47.9)	60.6 (57.7,63.4)
	US Asians	21.0 (10.3,31.7)	6.4 (2.8,9.9)	39.4 (18.1,60.7)	42.9 (13.3,72.4)
	US Blacks	29.0 (24.2,33.8)	15.0 (7.5,22.6)	17.5 (9.5,25.6)	38.4 (30.6,46.2)
	US Hispanics	25.2 (20.1,30.4)	1.3 (–1.4,4.1)	11.8 (7.0,16.6)	43.9 (34.2,53.7)
	US Whites	29.8 (23.6,35.9)	12.4 (3.8,20.9)	22.0 (14.8,29.2)	49.4 (39.2,59.5)

\*Harmonized definition released by American Heart Association 2009.

**Appendix Table 2**

Associations (odds ratios [95% CI]) between race/ethnic group and combined dysglycemia and dyslipidemia within BMI category

		Total; BMI 18.5–30+		BMI 18.5–25 kg/m <sup>2</sup>		BMI 25–30 kg/m <sup>2</sup>	
		Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Relative Odds of Combined Dysglycemia and							
Men	Resident South Asians	1.91 (1.45–2.51)	1.94 (1.48–2.54)	4.71 (2.41–9.20)	4.98 (2.46–10.07)	2.57 (1.48–4.49)	2.43 (1.39–4.21)
	US Asians	0.95 (0.60–1.50)	0.96 (0.62–1.51)	1.89 (0.75–4.76)	1.93 (0.74–5.04)	1.39 (0.71–2.71)	1.33 (0.62–2.85)
	US Blacks	0.30 (0.15–0.59)	0.30 (0.16–0.60)	0.66 (0.13–3.46)	0.71 (0.13–3.88)	0.24 (0.08–0.71)	0.25 (0.08–0.80)
	US Hispanics	1.07 (0.80–1.43)	1.12 (0.83–1.50)	1.09 (0.30–4.04)	1.24 (0.32–4.72)	1.31 (0.67–2.57)	1.26 (0.66–2.44)
	US Whites	1.0	1.0	1.0	1.0	1.0	1.0
Women	Resident South Asians	2.29 (1.40–3.76)	2.55 (1.53–4.27)	5.37 (2.01–14.29)	9.09 (2.48–33.29)	2.78 (1.25–6.20)	3.14 (1.34–7.35)
	US Asians	0.77 (0.38–1.55)	0.86 (0.43–1.72)	0.95 (0.16–5.66)	0.89 (0.15–5.41)	2.58 (1.05–6.35)	2.40 (0.88–6.61)
	US Blacks	0.47 (0.23–0.93)	0.50 (0.25–1.02)	0.66 (0.18–2.50)	0.93 (0.25–3.38)	0.21 (0.05–1.01)	0.11 (0.01–1.10)
	US Hispanics	1.04 (0.57–1.88)	1.16 (0.63–2.13)	0.96 (0.16–5.75)	1.67 (0.24–11.44)	0.37 (0.17–0.78)	0.47 (0.23–0.95)
	US Whites	1.0	1.0	1.0	1.0	1.0	1.0
Sensitivity Analysis: Relative Odds of “Metabolically Obese”							
Men	Resident South Asians	0.98 (0.79–1.21)	1.27 (1.00–1.60)	2.74 (1.40–5.36)	3.73 (1.90–7.36)	2.17 (1.54–3.05)	2.64 (1.86–3.80)
	US Asians	0.71 (0.43–1.17)	0.78 (0.46–1.31)	1.31 (0.59–2.92)	1.62 (0.74–3.53)	1.63 (0.89–2.98)	1.65 (0.89–3.05)
	US Blacks	0.46 (0.29–0.71)	0.52 (0.32–0.84)	0.74 (0.31–1.76)	0.87 (0.40–1.89)	0.23 (0.13–0.41)	0.23 (0.12–0.44)
	US Hispanics	0.94 (0.69–1.28)	1.32 (0.94–1.84)	0.24 (0.02–2.55)	0.37 (0.04–3.49)	0.97 (0.61–1.55)	1.21 (0.73–2.03)
	US Whites	1.0	1.0	1.0	1.0	1.0	1.0
Women	Resident South Asians	1.59 (1.16–2.19)	2.40 (1.67–3.44)	2.05 (1.03–4.08)	4.13 (1.65–10.32)	2.17 (1.36–3.45)	3.11 (1.88–5.44)
	US Asians	0.63 (0.34–1.19)	0.72 (0.39–1.32)	0.68 (0.33–1.38)	0.85 (0.35–2.04)	1.76 (0.77–4.00)	1.88 (0.80–4.41)
	US Blacks	0.99 (0.68–1.44)	1.26 (0.80–1.99)	1.72 (0.81–3.68)	2.03 (0.76–5.44)	0.75 (0.37–1.52)	0.89 (0.42–1.88)
	US Hispanics	0.77 (0.55–1.08)	1.04 (0.75–1.46)	0.15 (0.02–1.21)	0.27 (0.03–2.21)	0.47 (0.27–0.81)	0.59 (0.35–0.97)
	US Whites	1.0	1.0	1.0	1.0	1.0	1.0

\*FPG>126 mg/dL and triglyceride:HDL ratio > 4.

\*\* Harmonized definition released by American Heart Association 2009.

### Appendix Table 3

Sensitivity Analysis: Prevalence of combined dysglycemia and dyslipidemia by Asian BMI categories

Sex	Demographic group	BMI 18.5–23*	BMI 23–25	BMI>25
Men	Resident South Asians	39.1 (35.1,43.2)	48.8 (44.5,53.0)	53.0 (50.1,55.9)
	US Asians	33.7 (6.6,60.8)	44.2 (17.7,70.6)	44.3 (34.6,54.0)
	US Blacks	10.2 (–6.9,27.3)	12.2 (–12.7,37.0)	14.5 (7.1,21.8)
	US Hispanics	0.0 (0.0,0.0)	49.2 (23.8,74.6)	36.5 (30.0,42.9)
	US Whites	19.1 (2.0,36.2)	23.4 (–5.8,52.7)	34.8 (27.9,41.7)
Women	Resident South Asians	16.9 (13.1,20.7)	22.6 (17.8,27.4)	27.5 (25.5,29.6)
	US Asians	5.4 (–2.4,13.1)	1.6 (–2.0,5.2)	25.7 (16.9,34.5)
	US Blacks	0.0 (0.0,0.0)	5.6 (–4.3,15.6)	7.3 (3.6,11.1)
	US Hispanics	0.0 (0.0,0.0)	5.1 (–1.3,11.6)	12.5 (6.1,18.9)
	US Whites	3.4 (–3.4,10.3)	5.1 (–0.5,10.6)	15.4 (8.3,22.5)

\* There were 30 or fewer individuals in each of the US groups at this BMI level.

## Abbreviations

<b>BMI</b>	body mass index
<b>TG</b>	triglycerides
<b>HDL</b>	high density lipoprotein cholesterol
<b>FPG</b>	fasting plasma glucose

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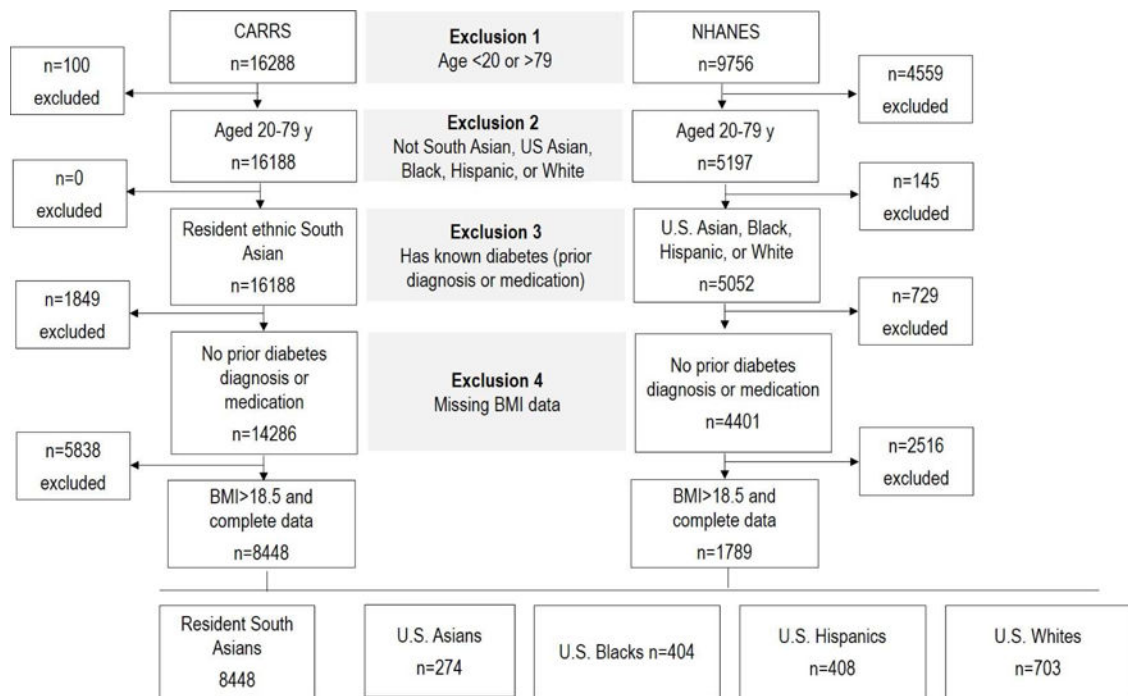
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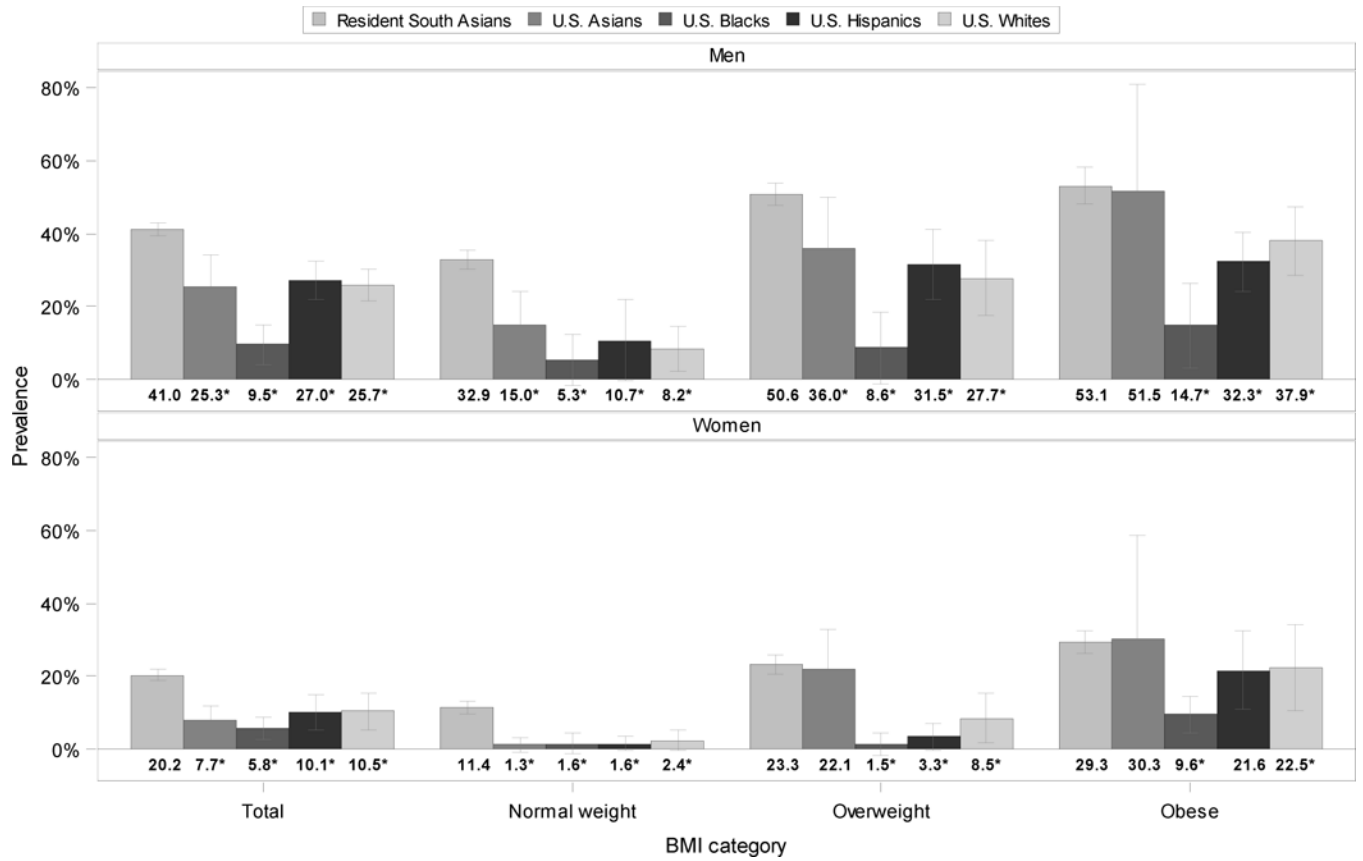
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**Highlights**

- Dysglycemia and dyslipidemia at normal weight characterize the South Asian phenotype
- 8%–15% of US men and 1%–2% of US women possess this phenotype
- Resident South Asians exhibited this phenotype 5–9 times more often than US adults

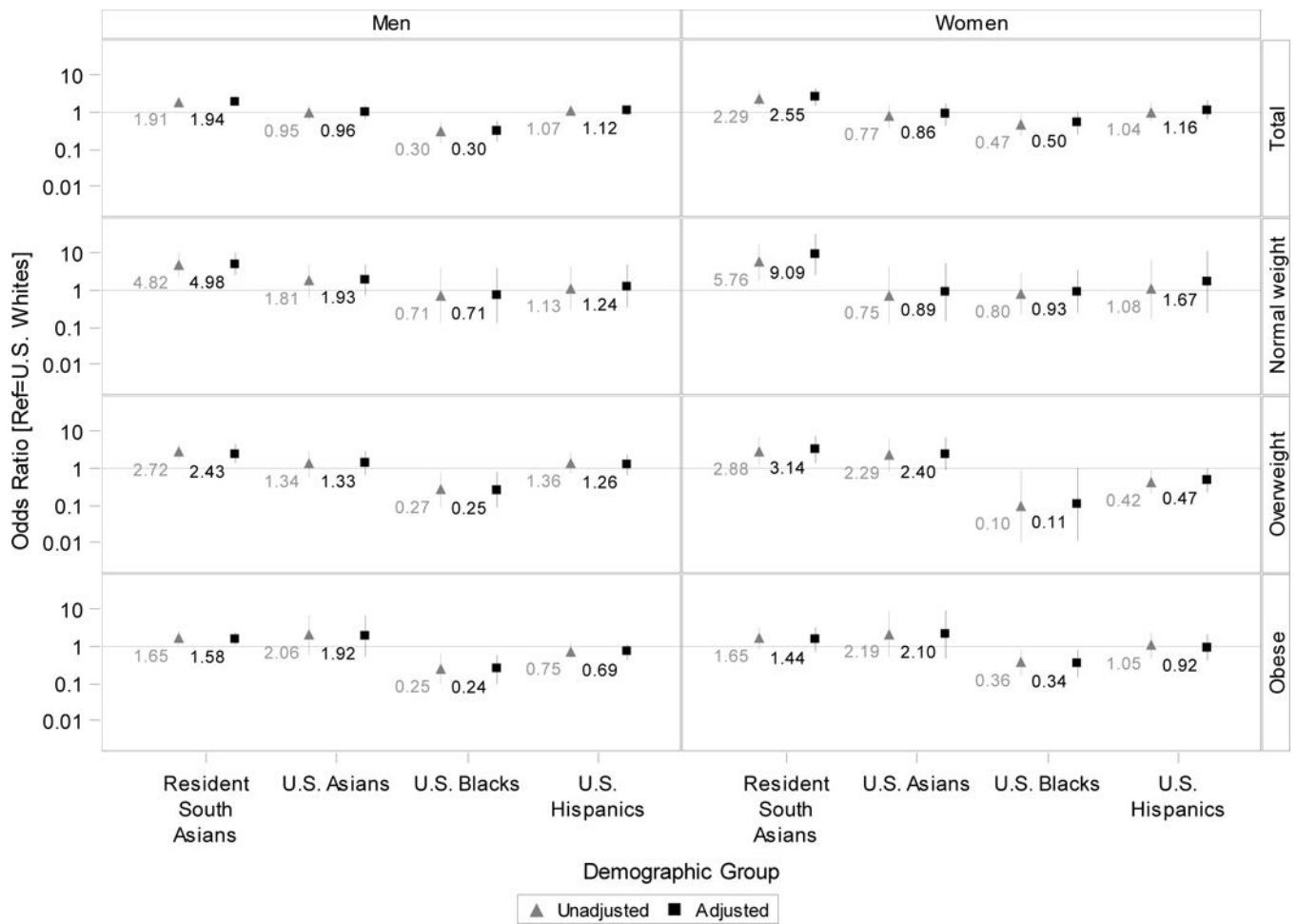


**Figure 1.** Participant exclusion criteria and sample size after each stage of restriction



**Figure 2. Prevalence of combined dysglycemia and dyslipidemia by demographic group within each BMI category**

\*p<.05 for difference in combined dysglycemia and dyslipidemia prevalence between resident South Asians (referent) and other race/ethnic groups.



**Figure 3. Relative odds of combined dysglycemia and dyslipidemia associated with race/ethnic groups by BMI category**

Odds ratios are plotted on a logarithmic axis (base 10) to better display positive and inverse associations on the same chart. The horizontal line marks the null value (odds ratio=1).



Table 1

Characteristics of CARRS and NHANES participants by sex and race/ethnicity

Sex	Demographic Group	n	Age, y	College educated, %	Tobacco user, %	BMI, kg/m <sup>2</sup>	HDL <sub>c</sub> , mg/dL	Triglycerides, mg/dL	Triglyceride:HDL ratio	FPG, mg/dL
Men	Resident South Asians	370 <sup>5</sup>	38.69±0.31	21.5±1.7	39.6±1.6	24.84±0.15	38.2 (33.0–45.1)	133.8 (96.8–195.3)	3.4 (2.3–5.5)	93.8 (87.4–102.2)
	U.S. Asians	143	37.36±1.58	78.0±3.4	21.3±4.1	24.86±0.55	46.9 (39.9–54.8)	113.1 (77.6–176.6)	2.5 (1.5–4.0)	99.2 (93.9–104.5)
	U.S. Blacks	175	37.36±1.19	49.4±5.8	26.0±4.3	28.55±0.61	47.9 (42.0–57.9)	80.7 (58.0–118.7)	1.7 (1.1–2.6)	95.9 (89.3–102.8)
	U.S. Hispanics	219	34.83±0.94	35.6±4.6	22.6±4.5	28.89±0.43	43.4 (38.6–50.1)	116.3 (86.6–168.4)	2.5 (1.8–4.2)	99.2 (94.0–105.3)
	U.S. Whites	354	40.93±0.79	67.1±4.6	26.7±3.5	28.37±0.31	45.8 (39.4–52.4)	119.6 (79.4–162.3)	2.6 (1.5–4.0)	98.2 (92.0–104.7)
Women	Resident South Asians	474 <sup>3</sup>	37.59±0.32	13.1±1.4	5.0±0.5	26.84±0.13	43.0 (37.1–49.4)	108.1 (79.6–146.6)	2.5 (1.7–3.6)	94.4 (88.2–102.2)
	U.S. Asians	131	38.90±1.03	79.4±3.3	6.0±2.4	23.53±0.39	57.8 (48.6–69.9)	89.1 (66.2–119.9)	1.4 (1.0–2.4)	93.8 (88.4–100.5)
	U.S. Blacks	229	38.09±0.75	67.4±4.2	19.5±2.7	31.53±0.60	56.1 (47.8–66.4)	73.9 (54.1–100.6)	1.3 (0.9–1.9)	93.9 (88.0–101.3)
	U.S. Hispanics	189	36.88±1.14	43.2±4.9	6.0±2.1	29.27±0.44	53.0 (45.6–61.9)	98.4 (67.4–135.1)	1.8 (1.2–2.8)	93.4 (88.6–99.3)
	U.S. Whites	349	42.38±0.96	80.2±3.4	17.8±2.3	28.25±0.51	55.9 (47.8–64.6)	98.9 (74.2–135.2)	1.8 (1.2–2.7)	93.7 (88.0–101.3)

Reported values are mean ±SE unless otherwise noted.

\* Median (interquartile range) is reported.