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, and high triglycerides at normal ranges of body weight) continues to be disproportionately exhibited by contemporary South Asians relative to other race/ethnic groups.

Objectives: We assessed the distinctiveness of the South Asian cardiometabolic profile by comparing the prevalence of combined high glucose, high triglycerides, and low high-density lipoprotein cholesterol (combined dysglycemia and dyslipidemia) in resident South Asians with 4 race/ethnic groups in the United States (Asians, black persons, Hispanics, and white persons) overall and by body mass index (BMI) category.

Methods: South Asian data were from the 2010 to 2011 Center for Cardiometabolic Risk Reduction in South Asia Study, representative of Chennai and New Delhi, India and Karachi, Pakistan. U.S. data were from the 2011 to 2012 National Health and Nutrition Examination Survey, representative of the U.S. population. Combined dysglycemia and dyslipidemia was defined as fasting blood glucose $\geq$126 mg/dl and triglyceride/high-density lipoprotein cholesterol ratio >4. Logistic regression was used to estimate the relative odds and 95% confidence intervals of combined dysglycemia and dyslipidemia associated with each race/ethnic group (referent, U.S. white persons). Models were estimated among adults aged 20 to 79 years by sex and BMI category and accounted for age, education, and tobacco use. Data from 8,448 resident South Asians, 274 U.S. Asians, 404 U.S. black persons, 308 U.S. Hispanics, and 703 U.S. white persons without previously known diabetes were analyzed.

Results: In the normal body weight range of BMI 18.5 to 24.9 kg/m^2, the prevalence of combined dysglycemia and dyslipidemia among men and women, respectively, was 33% and 11% in resident South Asians, 15% and 1% in U.S. Asians, 5% and 2% in U.S. black persons, 11% and 2% in U.S. Hispanics, and 8% and 2% in U.S. white persons. Compared with U.S. whites persons, 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 U.S. white persons was observed at normal weight (adjusted odds ratio: 4.98; 95% confidence interval: 2.46 to 10.07 for men) (adjusted odds ratio: 9.09; 95% confidence interval: 2.48 to 33.29 for women).

Conclusions: Between 8% and 15% of U.S. men and 1% and 2% of U.S. women of diverse race/ethnic backgrounds exhibited dysglycemia and dyslipidemia at levels of body weight 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 U.S. race/ethnic group.

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 weight according to body mass index (BMI); 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

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dyslipidemias (e.g., low levels of high-density lipoprotein cholesterol [HDL], high levels of triglycerides and low-density lipoprotein, 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 and cardiovascular mortality among migrant South Asians relative to local populations in diaspora settings that date back several decades [4–8].

Although cardiometabolic risk associated with South Asian race/ethnicity may reflect any combination of shared environmental exposures and stressors, genetic predisposition, behaviors, or social circumstances in migrant and native 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 [9–13]. Recently observed transitions from undernutrition to overnutrition, however, seem to be altering the low average body weight 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 trends toward excess body weight in urban South Asians, we assessed the distinctiveness of contemporary urban South Asians with respect to their cardiometabolic phenotype. Specifically, we compared the prevalence of the combination of high fasting plasma glucose (FPG) and high triglycerides relative to HDL in resident South Asians with prevalence of this combination in 4 race/ethnic groups residing in the United States (Asians, black persons, Hispanics, and white persons) at varying levels of body weight defined by BMI classification. 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 2 large population-based, representative samples: the 2010 to 2011 wave of the Center for Cardiometabolic Risk Reduction in South Asia Study (CARRS) and 2011 to 2012 National Health and Nutrition Examination Survey (NHANES). CARRS is an ongoing cohort study designed to be representative of nonpregnant adults aged 20 years and older residing in Chennai and New Delhi, India and Karachi, Pakistan in 2010 to 2011. NHANES is a biennial cross-sectional study designed to be representative of the U.S. population. Details of both studies are published [20,21]. We restricted the current analysis to adults aged 20 to 79 years in demographic groups of interest without a prior diagnosis of diabetes (self-reported), with complete anthropometric (height, weight) and laboratory assessments (FPG, triglycerides, HDL), and BMI >18.5. A total of 8,448 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 4 groups: 1) U.S. Asians; 2) U.S. black persons; 3) U.S. Hispanics; and 4) U.S. white persons. All NHANES participants beyond these categories were excluded from analysis. The U.S. Asian group was composed of both East Asians and South Asians, and the publicly available NHANES data do not allow for distinguishing between these 2 groups.

Body weight classification

We defined body weight categories following the international classification of BMI. A BMI <18.5 was excluded. BMI ranging from 18.5 to 24.9 kg/m^2 was considered "normal weight," BMI ranging from 25 to 30 was considered "overweight," and BMI >30 was considered "obese." These 3 categories of body weight were used in the primary analysis.

Combined dysglycemia and dyslipidemia

We defined combined dysglycemia and dyslipidemia as the presence of FPG ≥126 mg/dl *and* triglyceride to 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 8 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 3 laboratories used by CARRS participated in a Randox International Quality Assessment Scheme that standardized findings to a central laboratory at the Public

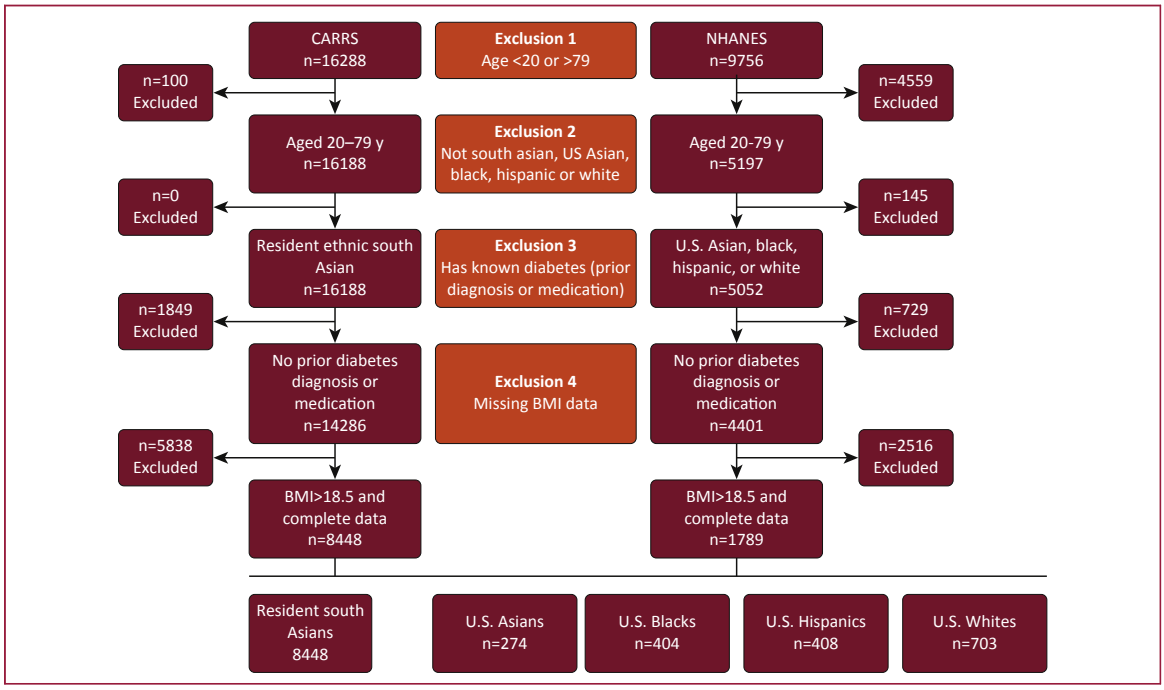

FIGURE 1. Participant exclusion criteria and sample size after each stage of restriction. BMI, body mass index; CARRS, Center for Cardiometabolic Risk Reduction in South Asia Study; NHANES, National Health and Nutrition Examination Survey.

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 9 hours or more were assigned positive analytic weights. NHANES samples were analyzed at the University of Minnesota; vials were stored at −20°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 analyses

Survey weights were recalculated to age-standardize each group to the World Health Organization standard population structure in descriptive analysis [22]. Analyses described the prevalence of combined dysglycemia and dyslipidemia by race/ethnic 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 [CIs]) of combined dysglycemia and dyslipidemia for each race/ethnic group relative to U.S. white persons. U.S. white persons, instead of resident South Asians, were used as the referent in the logistic models because U.S. white persons were the largest U.S. 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 2 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 ≥150 mg/dl, systolic blood pressure ≥130 or diastolic blood pressure ≥85 mm Hg or hypertension medication, FPG ≥100 mg/dl or medication, and 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 to 22.9 kg/m^2 as normal, 23 to 24.9 kg/m^2 as overweight, and 25 kg/m^2 or higher 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 to 2012 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 U.S. Asians, 404 U.S. black persons, 308 U.S. Hispanics, and 703 U.S. white persons 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 U.S. Asians. Tobacco use was highest in South Asians (40%) among men and in U.S. white persons (18%) among women. Mean BMI was highest in U.S. Hispanics (28.89 ± 0.43 kg/m^2) among men and in U.S. black persons (31.53 ± 0.60 kg/m^2) among women. Notably, South Asian men had mean BMI comparable with U.S. Asian men (24.84 vs. 24.86 kg/m^2, respectively) and South Asian women had significantly higher mean BMI than U.S. Asian women (26.84 vs. 23.53 kg/m^2, respectively). Mean BMI among South and U.S. Asians was lower than that of any other group.

Figure 2 and Online Table 1 show the prevalence of combined dysglycemia and dyslipidemia, defined as FPG ≥126 and triglyceride/HDL ratio >4, by race/ethnic group. Combining all BMI categories, South Asians had the highest prevalence, 41% and 20% in men and women, respectively. In the normal body weight range of BMI 18.5 to 24.9 kg/m^2, prevalence was 33% and 11% in resident South Asian, 15% and 1% in U.S. Asians, 5% and 2% in U.S. black persons, 11% and 2% in U.S. Hispanics, and 8% and 2% in U.S. white men and women, respectively. Compared with South Asian men, the prevalence of combined dysglycemia and dyslipidemia was statistically significantly lower in U.S. black, Hispanic, and white men at all body weight levels, whereas prevalence in U.S. Asian men was significantly lower only in the normal (BMI 25.0 to 29.9 kg/m^2) and overweight range (≥30.0 kg/m^2). Compared with South Asian women, the prevalence of combined dysglycemia and dyslipidemia was statistically significantly lower among U.S. Asian, black, Hispanic, and white women at all body weight 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 (range: 5% to 33% among men and 1% to 2% among women) and highest in the obese group (range: 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 body weight category for all race/ethnic groups.

TABLE 1. Characteristics of CARRS and NHANES participants by sex and race/ethnicity

Sex	Demographic Group	N	Age, years	College Educated, %	Tobacco User, %	BMI, kg/m^2	HDL*, mg/dl	Triglycerides*, mg/dl	Triglyceride/HDL Ratio*	FPG*, mg/dl
Men	Resident South Asians	3,705	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. black persons	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. white persons	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	4,743	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. black persons	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. white persons	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. BMI, body mass index; CARRS, Center for Cardiometabolic Risk Reduction in South Asia Study; FPG, fasting plasma glucose; HDL, high-density lipoprotein cholesterol; NHANES, National Health and Nutrition Examination Survey.
*Median (interquartile range) is reported.

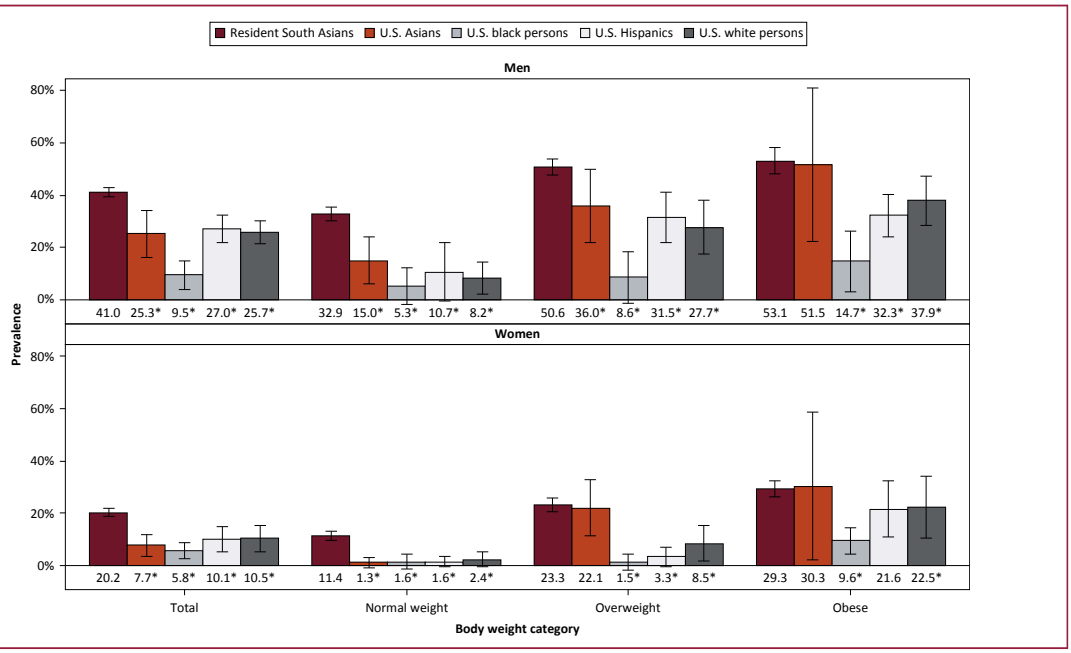

FIGURE 2. Prevalence of combined dysglycemia and dyslipidemia by demographic group within each body weight category. *$p < 0.05$ for difference in combined dysglycemia and dyslipidemia prevalence between resident South Asians (referent) and other race/ethnic groups. Abbreviation as in Figure 1.

Figure 3 and Online Table 2 show the relative odds of combined dysglycemia and dyslipidemia associated with race/ethnic group (referent, U.S. white persons) overall and by body weight. Compared with U.S. white persons, adjusted relative odds (aOR; 95% CIs) of combined dysglycemia and dyslipidemia were aOR 1.94 (95% CI: 1.48 to 2.54) and aOR 2.55 (95% CI: 1.53 to 4.27) for South Asian men and women, respectively. At each body weight category, with the exception of obese women, South Asian ethnicity was associated with the highest aOR of combined dysglycemia and dyslipidemia. Comparing South Asians with U.S. white persons, odds ratios tended to be largest in the normal weight range and smallest in the obese range. Normal-weight South Asian men were nearly 5 times as likely to have combined dysglycemia and dyslipidemia as normal-weight U.S. white men (aOR: 4.98; 95% CI: 2.46 to 10.07). South Asian women had greater odds of combined dysglycemia and dyslipidemia compared with U.S. women in the normal (aOR: 9.09; 95% CI: 2.48 to 33.29) and overweight (aOR: 3.14; 95% CI: 1.34 to 7.36), but not obese, body weight range. With the exception of U.S. black men (OR: 0.30; 95% CI: 0.16 to 0.60), no other U.S. group statistically differed from U.S. white persons with respect to combined dysglycemia and dyslipidemia in the overall sample. In analyses stratified by body weight, relative to U.S. white persons, 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.

Online Tables 1 and 2 show the sensitivity analysis examining metabolic syndrome by body weight categories and race/ethnicity. The prevalence of metabolic syndrome was between 1.5 and 5 times higher than that of combined dysglycemia and dyslipidemia in U.S. black, Hispanic, and white men and in women of all race/ethnic groups (Online Table 1). The aOR of metabolic syndrome was higher among South Asians compared with U.S. white persons at all levels of body weight; associations were attenuated compared with those observed for combined dysglycemia and dyslipidemia. Online Table 3 shows the sensitivity analysis examining combined dysglycemia and dyslipidemia within body weight categories suggested for Asians. South Asians had the highest prevalence of combined dysglycemia and dyslipidemia in all categories of body weight defined using Asian-specific BMI thresholds.

DISCUSSION

Between 11% and 15% of U.S. men and 1% and 2% of U.S. women of varying race/ethnic backgrounds exhibited combined dysglycemia and dyslipidemia at levels of body weight considered healthy (i.e., normal weight range of BMI 18.5 to 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 U.S. race/ethnic group. These findings, based on recent population-based data of multiple race/ethnic

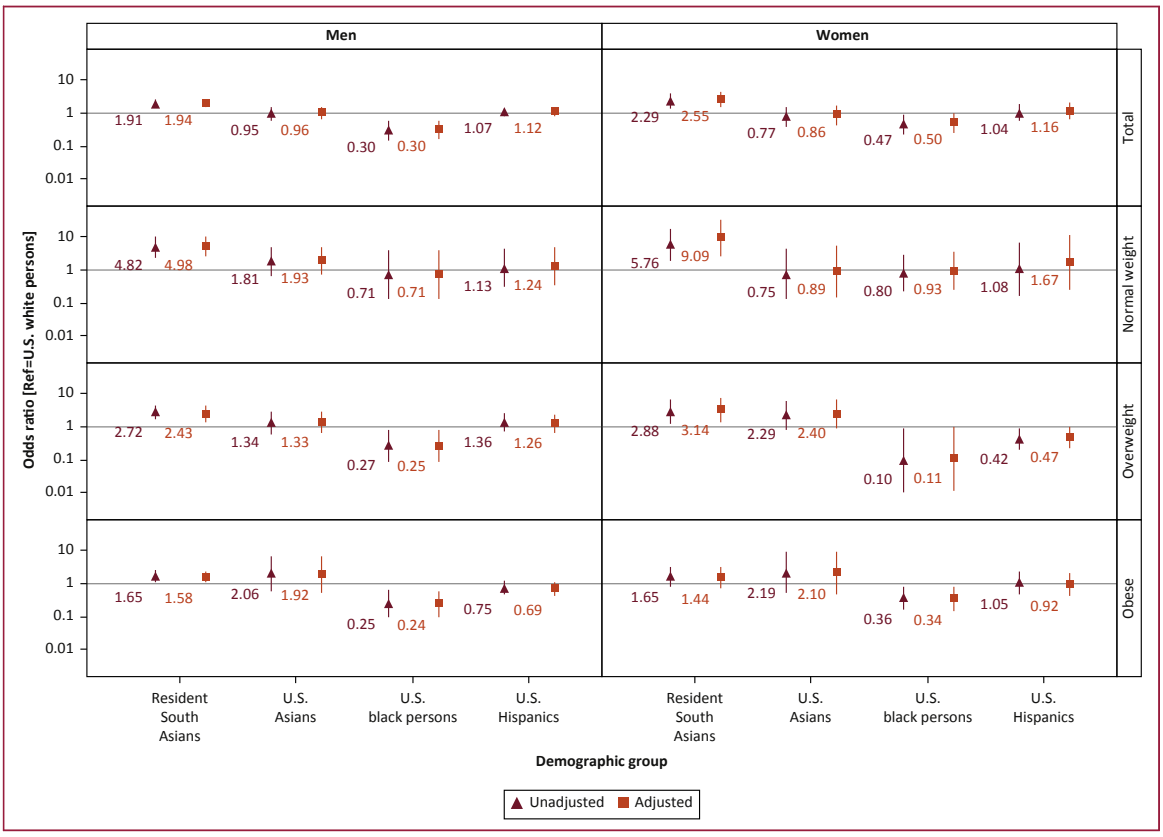

FIGURE 3. Relative odds of combined dysglycemia and dyslipidemia associated with race/ethnic groups by body weight category. Odds ratios are plotted on a logarithmic axis (base 10) to better display positive and inverse associations on the same chart. The horizontal line marks the null value (odds ratio: 1).

groups, are consistent with a large body of literature reporting that South Asians tend to experience worse cardiometabolic health despite lower BMI 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 U.S. 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 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, resident South Asians continue to exhibit disproportionately higher specific glucose-associated dyslipidemias at levels disproportionately higher than other race/ethnic 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 to 1993 to 21% in 2005 to 2006 [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 caused by a combination of hereditary, environmental, cultural, or 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. However, we 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 U.S. white persons at normal weight. This is reassuring that the ethnic differences reported here are robust to an alternate, broader definition of metabolic risk that incorporated abdominal adiposity and hypertension and included persons with diabetes. Further investigation may benefit from examining measures of cardiometabolic risk (FPG, triglycerides, HDL, hypertension) separately to better understand specific 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.

CONCLUSIONS

We sought to investigate the distinctiveness of the South Asian cardiometabolic phenotype by describing cardiometabolic risk by BMI classification for 5 groups defined by contrasting race/ethnic and residential characteristics: 1) resident South Asians; 2) U.S. Asians; 3) U.S. Hispanics; 4) U.S. black persons; and 5) U.S. white persons. In doing so, the study had several strengths. We combined 2 recent, large population-based datasets with fairly comprehensive anthropometric and metabolic assessments to shed light on cardiometabolic health in resident South Asians and U.S. populations of diverse race/ethnic background. Participants were assessed close in calendar time, diminishing concerns regarding differences caused by secular changes in cardiometabolic health. We included multiple race/ethnic comparison groups residing in the United States. Future investigation may fruitfully pool prospective data from multiple sources to disentangle the modifiable causes of observed differences between resident South Asians and U.S. groups to better guide intervention efforts.

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APPENDIX

ONLINE TABLE 1. Prevalence (95% CI) of combined dysglycemia and dyslipidemia by demographic group by body weight 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 and TG/HDL >4)					
Men	Resident South Asians	41.0 (39.3 to 42.7)	32.9 (30.2 to 35.6)	50.6 (47.6 to 53.7)	53.1 (48.0 to 58.1)
	U.S. Asians	25.3 (16.3 to 34.3)	15.0 (6.0 to 24.0)	36.0 (22.1 to 49.8)	51.5 (22.1 to 80.9)
	U.S. black persons	9.5 (3.9 to 15.1)	5.3 (−1.7 to 12.4)	8.6 (−1.1 to 18.3)	14.7 (3.3 to 26.2)
	U.S. Hispanics	27.0 (21.8 to 32.2)	10.7 (−0.5 to 22.0)	31.5 (21.9 to 41.0)	32.3 (24.2 to 40.3)
	U.S. white persons	25.7 (21.3 to 30.2)	8.2 (2.0 to 14.3)	27.7 (17.4 to 38.1)	37.9 (28.5 to 47.3)
Women	Resident South Asians	20.2 (18.8 to 21.7)	11.4 (9.7 to 13.0)	23.3 (20.8 to 25.8)	29.3 (26.1 to 32.6)
	U.S. Asians	7.7 (3.7 to 11.8)	1.3 (−0.7 to 3.3)	22.1 (11.5 to 32.7)	30.3 (2.1 to 58.5)
	U.S. black persons	5.8 (2.7 to 8.9)	1.6 (−1.5 to 4.6)	1.5 (−1.5 to 4.5)	9.6 (4.6 to 14.6)
	U.S. Hispanics	10.1 (5.4 to 14.8)	1.6 (−0.5 to 3.6)	3.3 (−0.2 to 6.9)	21.6 (11.0 to 32.2)
	U.S. white persons	10.5 (5.5 to 15.5)	2.4 (−0.3 to 5.1)	8.5 (1.9 to 15.2)	22.5 (10.7 to 34.3)
Metabolic Syndrome*					
Men	Resident South Asians	47.4 (45.5 to 49.3)	31.8 (29.6 to 34.0)	66.4 (63.5 to 69.3)	80.0 (76.6 to 83.4)
	U.S. Asians	41.5 (29.0 to 54.0)	16.2 (4.8 to 27.7)	61.7 (48.0 to 75.4)	69.4 (43.0 to 95.9)
	U.S. black persons	28.1 (19.9 to 36.4)	10.4 (0.8 to 20.0)	11.6 (6.0 to 17.2)	53.3 (38.0 to 68.6)
	U.S. Hispanics	47.9 (40.7 to 55.2)	5.0 (−6.1 to 16.1)	44.3 (35.4 to 53.3)	61.8 (55.6 to 68.0)
	U.S. white persons	48.7 (43.3 to 54.1)	11.7 (3.0 to 20.4)	45.1 (36.6 to 53.5)	67.2 (57.9 to 76.5)
Women	Resident South Asians	42.0 (39.9 to 44.1)	23.7 (20.7 to 26.7)	44.6 (41.3 to 47.9)	60.6 (57.7 to 63.4)
	U.S. Asians	21.0 (10.3 to 31.7)	6.4 (2.8 to 9.9)	39.4 (18.1 to 60.7)	42.9 (13.3 to 72.4)
	U.S. black persons	29.0 (24.2 to 33.8)	15.0 (7.5 to 22.6)	17.5 (9.5 to 25.6)	38.4 (30.6 to 46.2)
	U.S. Hispanics	25.2 (20.1 to 30.4)	1.3 (−1.4 to 4.1)	11.8 (7.0 to 16.6)	43.9 (34.2 to 53.7)
	U.S. white persons	29.8 (23.6 to 35.9)	12.4 (3.8 to 20.9)	22.0 (14.8 to 29.2)	49.4 (39.2 to 59.5)

BMI, body mass index; CI, confidence interval; FPG, fasting plasma glucose; HDL, high-density lipoprotein cholesterol; TG, triglycerides.
*Harmonized definition released by American Heart Association 2009.

ONLINE TABLE 2. Associations (odds ratios [95% CI]) between race/ethnic group and combined dysglycemia and dyslipidemia by body weight category

	Total: BMI 18.5–30+		Normal Weight: BMI 18.5–25 kg/m^2		Overweight: BMI 25–30 kg/m^2		Obese: BMI >30 kg/m^2	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Relative Odds of Combined Dysglycemia and Dyslipidemia*								
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 (1.39–4.24)	1.65 (1.05–2.58)	1.58 (1.05–2.36)
U.S. 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)	2.16 (0.66–7.08)	1.92 (0.53–6.92)
U.S. black persons	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 (0.08–0.76)	0.27 (0.12–0.60)	0.24 (0.10–0.59)
U.S. 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 (0.66–2.42)	0.74 (0.47–1.17)	0.69 (0.43–1.11)
U.S. white persons	1.0	1.0	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 (1.34–7.36)	1.70 (0.82–3.50)	1.44 (0.68–3.04)
U.S. 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 (0.88–6.58)	1.65 (0.43–6.32)	2.10 (0.46–9.64)
U.S. black persons	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 (0.01–1.00)	0.38 (0.17–0.84)	0.34 (0.15–0.77)
U.S. 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 (0.23–0.97)	1.00 (0.47–2.15)	0.92 (0.42–2.04)
U.S. white persons	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sensitivity Analysis: Relative Odds of Metabolic Syndrome†								
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 (1.86–3.74)	1.64 (1.06–2.54)	1.76 (1.08–2.87)
U.S. 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 (0.89–3.06)	1.09 (0.30–4.01)	1.70 (0.52–5.58)
U.S. black persons	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 (0.12–0.45)	0.58 (0.32–1.05)	0.65 (0.36–1.17)
U.S. 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 (0.73–2.01)	0.79 (0.52–1.20)	1.11 (0.68–1.79)
U.S. white persons	1.0	1.0	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 (1.88–5.16)	1.49 (0.96–2.32)	2.28 (1.37–3.78)
U.S. 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 (0.80–4.42)	0.87 (0.27–2.83)	1.18 (0.37–3.72)
U.S. black persons	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 (0.42–1.87)	0.67 (0.40–1.12)	0.84 (0.49–1.43)
U.S. 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 (0.35–0.99)	0.78 (0.52–1.18)	0.99 (0.65–1.50)
U.S. white persons	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Abbreviations as in Online Table 1.

*FPG >126 mg/dl and triglyceride/HDL ratio >4.

†Harmonized definition released by American Heart Association 2009.

ONLINE TABLE 3. Sensitivity analysis: prevalence of combined dysglycemia and dyslipidemia by body weight category defined using Asian BMI thresholds

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

Abbreviations as in Online Table 1.

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