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Authors

Bharmal, Nazleen
Kaplan, Robert M
Shapiro, Martin F
et al.

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ORIGINAL PAPER

The Association of Duration of Residence in the United States with Cardiovascular Disease Risk Factors Among South Asian Immigrants

Nazleen Bharmal · Robert M. Kaplan · Martin F. Shapiro · Carol M. Mangione · Marjorie Kagawa-Singer · Mitchell D. Wong · William J. McCarthy

Abstract South Asians are disproportionately impacted by cardiovascular disease (CVD). Our objective was to examine the association between duration of residence in the US and CVD risk factors among South Asian adult immigrants. Multivariate logistic regression analyses using pooled data from the 2005, 2007, 2009 California Health Interview Surveys. Duration of residence in the US <15 years was significantly associated with overweight/obese BMI (OR 0.59; 95 % CI 0.35, 0.98 for 5 to <10 years), daily consumption of 5+ servings of fruits/vegetables (OR 0.37; 95 % CI 0.15, 0.94 for 10 to <15 years), and sedentary lifestyle (OR 2.11; 95 % CI 1.17, 3.81 for 10 to <15 years) compared with duration of residence ≥15 years after adjusting for illness burden, healthcare access, and socio-demographic characteristics. Duration of residence was not significantly associated with other CVD risk factors. Duration of residence is an important correlate of overweight/obesity and other risk factors among South Asian immigrants.

Keywords Asian Americans · Immigrants · Acculturation · Cardiovascular disease · Risk factors · United States

N. Bharmal (✉) · M. F. Shapiro · C. M. Mangione · M. D. Wong
Division of General Internal Medicine and Health Services Research, Department of Medicine, University of California, 911 Broxton Avenue, Room 203, Los Angeles, CA 90095-1769, USA
e-mail: nbharmal@mednet.ucla.edu

R. M. Kaplan
National Institutes of Health, Office of Behavioral and Social Sciences Research, Bethesda, MD, USA

M. Kagawa-Singer
Department of Community Health Sciences, Fielding School of Public Health, University of California, Los Angeles, CA, USA

W. J. McCarthy
Department of Health Policy and Management, Department of Psychology, Fielding School of Public Health, University of California, Los Angeles, CA, USA

W. J. McCarthy
Division of Cancer Prevention and Control Research, Jonsson Comprehensive Cancer Center, University of Los Angeles, Los Angeles, CA, USA

Introduction

South Asians are people with origins in India, Pakistan, Bangladesh, Sri Lanka, Nepal, and Bhutan. They are among the fastest growing ethnic/immigrant groups in the United States (US), with a 70 % increase in the last decade [1]. California, the state with the largest population of South Asians, comprises 32 % of South Asians in the US [2].

People in South Asian countries have earlier incidence and greater premature mortality from cardiovascular disease (CVD) than people in Western countries, a disparity that persists for South Asian immigrants in developed countries [3–18]. A case–control comparison of age of first acute myocardial infarction between five South Asian countries and 47 other countries concluded that the observed disparities could be attributed to higher levels of standard risk factors at earlier ages in South Asians compared to citizens of other countries [5]. The authors speculated that the observed increase in CVD risk observed in South Asian countries could be attributed to the effects of increasing urbanization on CVD risk factors [5]. The

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nutritional consequences of migrating from a low-income country to the US are similar to the nutritional consequences of migrating from a rural lifestyle to an urban lifestyle and similar to the effects of "modernization" in developing countries [19–21]. These consequences include increases reported for various nutrition-related CVD risk factors, including increased intake of saturated fats (i.e., animal foods), refined carbohydrates, sodium and decreased intake of dietary fiber and potassium [5]. In California, South Asian men ages 25–44 years have three times the relative risk of death from CVD in comparison to the age-matched general population [4]. Epidemiologic studies have documented that South Asian immigrants have higher prevalence of medical CVD risk factors than the general population, such as diabetes, dyslipidemia, and metabolic syndrome, possibly due to a genetic predisposition to insulin resistance and central adiposity [6, 9, 11, 22–29]. They also have high rates of behavioral CVD risk factors, including physical inactivity and diets low in fruits and vegetables [9, 23–25, 28, 30, 31].

While there is not yet consensus that CVD risk is higher for South Asians in the US than in their country of origin, one likely influential factor of CVD risk is duration of residence in the US, which has been used as a proxy measure for acculturation [32–34]. Duration of residence in the US has been associated with increased rates of hypertension [35], hyperlipidemia [36, 37], diabetes [37, 38], obesity [35, 36, 39–42], and smoking [35, 36] among immigrants. In addition, immigrants who arrive in the US at younger ages may be at higher risk for diabetes and obesity with increasing duration of residence than immigrants who arrive at later ages, presumably because habits established in the country of origin were healthier than habits established in the US [38, 42]. However, these studies report findings aggregating all immigrant groups combined or all Asian immigrant groups. Given the considerable variability in CVD risk profile among Asians, these study results may not necessarily be representative of South Asians [43]. The impact of duration of residence in the US on South Asian immigrant cardiovascular risk is more often than not deleterious [37, 44, 45]. Several researchers have postulated that this increased CVD risk is attributable to South Asians adopting the diet and physical activity behaviors of a Western lifestyle after immigration, which may amplify their already increased genetic risk of CVD [43, 46, 47]. For example, South Asians with a longer duration of residence in the US may adopt a Western diet that is higher in saturated fat, refined sugars, and processed food products or a more sedentary lifestyle that has less leisure-time, transportation, and occupational physical activity than they would have in their country of origin [37, 44]. Our objective was to examine the association of duration of residence with CVD risk factors among South Asian adult immigrants using data from the California Health Interview Survey (CHIS).

Methods

The CHIS is a random-digit-dial telephone survey of households designed to be representative of California's non-institutionalized population. A two-stage, geographically stratified design was used to produce a representative sample. Telephone numbers were selected from predefined geographic areas, and respondents were then randomly selected from sampled households. Detailed information about the CHIS methodology is available elsewhere [48]. The protocol received institutional review board exemption because we used publicly available, de-identified data.

In our analyses, South Asians were identified through self-report of race/ethnicity and using definitions from the 2000 US. Census or based on self-reported origins from India, Pakistan, Bangladesh, Nepal, Sri Lanka, or Bhutan. Our analyses used the 2005, 2007, and 2009 CHIS and included responses from aggregated samples of South Asian adults aged 18 years and above (1,272/141,682 adult respondents) who were born outside of the US (1,169/1,272 South Asian adult respondents). Interview completion rates among adults were 54 % among all respondents in 2005, 53 % for landline respondents and 52 % for cell phone respondents in 2007, and 49 % for landline respondents and 56 % for cell phone respondents in 2009 [49–51].

Outcome Variables

The outcome variables included eight common CVD risk factors: (1) hypertension, (2) hypercholesterolemia, (3) diabetes, (4) overweight/obese body mass index, (5) cigarette smoking status, (6) binge drinking status, (7) physical activity, and (8) diet [52, 53]. Measures of the risk factors were included in each of the three survey years unless otherwise noted. Respondents were asked whether they had ever been told by a doctor that they have high blood pressure, high cholesterol in 2005 only, or diabetes (yes vs. no); responses for borderline diabetes were recoded as answering no (1.4 % of foreign-born South Asian adult subpopulation). Body mass index (BMI) was calculated from self-reported weight and height and dichotomized into healthy weight ($18.5 \geq$ BMI < 25 kg/m^2) or overweight/obese (BMI ≥ 25 kg/m^2) based on the World Health Organization classification scheme and clinical relevance [54]. Respondents with underweight BMI (BMI < 18.5 kg/m^2) were not included in the analysis because underweight could be an artifact of undiagnosed disease (3.3 % of the subpopulation). Cigarette smoking status was dichotomized into current smoker versus former or never smoker.

Respondents were classified as binge drinkers if they reported ≥5 alcoholic drinks for men or ≥4 alcoholic drinks for women on any occasion in the past month (yes vs. no). Physical activity (PA) was categorized as regular (150 min or more of moderate-intensity PA in past week), some (1 to <150 min of moderate PA in past week), or sedentary (no PA in past week) [53]. Physical activity was dichotomized into sedentary or regular/some physical activity. We used participants' ratings of how many and how often they ate fruits or vegetables to assess the healthfulness of their food choices. A variable was derived to indicate frequency of daily fruit and vegetable consumption [55]. As guidelines suggest a minimum of five daily servings of fruits and vegetables for adults [52, 55, 56], the variable representing frequency of fruits and vegetables consumed per day was dichotomized (0 = ate <5 times per day, 1 = ate five or more times per day). Cardiovascular disease reduction guidelines also suggest ≤36 oz per week of sugar-sweetened beverages, such as soda [52]. Respondents reported frequency of soda intake per week and this variable was dichotomized (0 = drank ≤3 sodas per week, 1 = drank 4 or more sodas per week); respondents were asked not to include diet soda in their responses. For the 2007 and 2009 CHIS, respondents reported fast food intake per week and this variable was dichotomized (0 = ate fast food at most once per week, 1 = ate fast food twice or more per week).

Predictor Variable: Duration of Residence in US

Duration of residence in the US was based on the answer to the question "About how long have you lived in the United States?" Temporal measures, although imperfect, have been used as proxies for acculturation in other studies [33]. Duration of residence in the US was initially categorized into one of the five following categories in the CHIS public-use datasets: <1, 1 to <5, 5 to <10, 10 to <15, 15+ years. Based on the distribution of responses, the first two categories were collapsed, resulting in four duration of residence categories used in the analyses. Age at the time of immigration was calculated by subtracting duration of residence in the US from current age.

Covariates

We considered illness burden, access to healthcare, and socio-demographic characteristics as covariates in the analyses. Some were considered to be independent predictors for CVD risk factors and others were considered important to include because they may attenuate associations between duration of residence in the US and CVD risk factors. We defined illness burden by using self-reported health status (excellent, very good, good, fair, poor), which has previously been shown to be associated with mortality in a multiethnic cohort [57]. We measured access to healthcare using the proxies of having health insurance (yes or no) or a usual source of care (yes or no). Socio-demographic characteristics included sex, marital status, level of educational attainment, and annual household income.

Statistical Analysis

We performed frequencies and cross-tabulations to describe the prevalence of baseline characteristics in the full sample. CVD risk factors by duration of residence in the US were compared using ANOVA for continuous variables and a χ^2 test for categorical variables. A test for linear trend was performed using the Cochran-Armitage test. Multivariate logistic regression analyses were performed to estimate the odds of each CVD risk factor in relation to the duration of residence in the US, adjusted for age at immigration, illness burden, healthcare access, and socio-demographics; of note, usual source of care was not included in the model because it was not available for all survey years. The reference category for duration of residence in the US was ≥15 years because it was the most prevalent group. Based on the frequency distributions in the subpopulation, we dichotomized marital status into married or not married, educational attainment into less than college degree or greater than or equal to college degree, annual household income into 0–199 % federal poverty level or 200 % or more of the federal poverty level, and health status into poor/fair/good health or excellent/very good health. Models with current age, age at immigration, and duration of residence in the US resulted in high levels of multicollinearity, which was expected because current age is the sum of duration of residence and age at immigration. Therefore, separate analyses were conducted that included current age and duration of residence in the first model and age at immigration and duration of residence in the second model. The results of the two models were comparable; as such, we only reported the results of the second model. We found no significant multicollinearity among the predictor variables in the final model.

Potential confounders were included in evaluations of several models because they might have been responsible for the association of duration of residence in the US with CVD risk factors. For hypertension, binge drinking and overweight/obese BMI were included as confounders. For high cholesterol, overweight/obese BMI was included as a confounder. For diabetes, overweight/obese BMI, binge drinking, sedentary lifestyle, and daily fruit/vegetable

Table 1 Sample characteristics of South Asian adult immigrants in the 2005, 2007, and 2009 CHIS[a]

Characteristic	n	% or mean
Age, mean (range: SE) in years	1,169	40.05 (18–85: 0.49)
Sex		
Male	617	57.6
Female	552	42.4
Marital status		
Married	949	76.9
Living with partner	11	0.7
Divorced/widowed/separated	89	4.3
Never married	120	18.2
Educational attainment		
<High school	28	2.6
High school degree/associates	185	15.9
College degree	388	32.3
Graduate/professional degree	568	49.2
Income		
0–99 % fed poverty level	68	7.3
100–199 % fed poverty level	96	7.6
200–299 % fed poverty level	100	8.2
300+ % fed poverty level	905	77.0
Health status		
Excellent	326	30.8
Very good	417	37.2
Good	340	26.9
Fair	66	3.4
Poor	20	1.6
Health insurance		
Yes	1,071	89.4
No	98	10.6
Usual source of care[b]		
Yes	677	88.3
No	75	11.7
Years lived in the US		
Mean score on 1–4 scale (range: SE), years	1,169	2.85 (1–4:0.05)
0 to <5 years	144	16.6
5 to <10 years	217	23
10 to <15 years	219	19.2
15+ years	589	41.2
Age at immigration		
Mean (range: SE), years	1,169	37.20 (14–81:0.46)
≤30 years old	285	32.9
31–40 years old	418	35.9
41–50 years old	214	15.4
>50 years old	252	15.7

[a] Percentages based on weighted, unadjusted data. Column totals may not equal 100 due to rounding error or missing observations

[b] Variable not available for all survey years: usual source of care (2005 and 2009 CHIS)

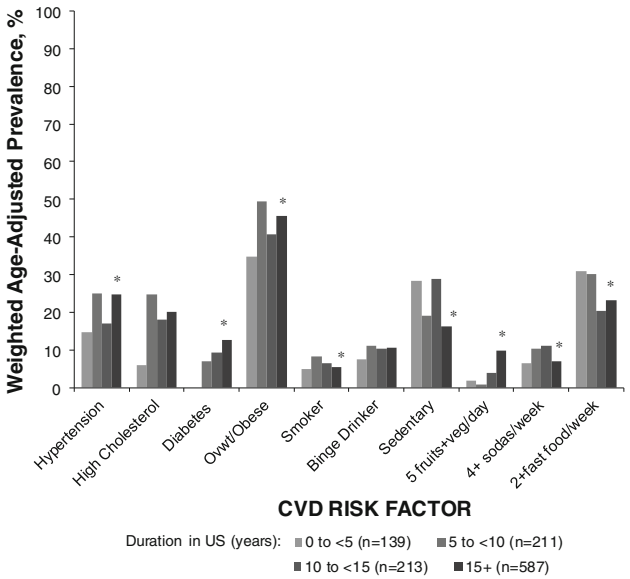

Fig. 1 CVD risk factor prevalence by duration of residence in the US among South Asian adult immigrants in the 2005, 2007, and 2009 CHIS, adjusted for age. *χ^2 test variable was significant ($p < 0.05$). The sample sizes for high cholesterol in the 2005 CHIS were: 0 to <5 (n = 43), 5 to <10 (n = 74), 10 to <15 (n = 59), 15+ (n = 156). The sample sizes for fast food in the 2007 and 2009 CHIS were: 0 to <5 (n = 83), 5 to <10 (n = 128), 10 to <15 (n = 148), 15+ (n = 420)

intake were included as confounders. For overweight/obesity, binge drinking, sedentary lifestyle, and daily fruit/vegetable intake were included as confounders.

The analytic sample was limited to South Asian adult immigrants who had non-missing values for the covariates; the sample size for each CVD risk factor model is reported in the results since it varied by outcome. Sample weights were used to account for the complex sampling design and adjusted to account for the pooled data. Analyses were performed using STATA 12.0 (College Station, TX).

Results

The majority of South Asian immigrants resided in the US for ≥15 years, and over half of all immigrants were younger than 40 years of age upon arrival in the US (Table 1). The mean current age was 40 years; most respondents were male, married, highly educated, and insured. The demographic profile of South Asians in the CHIS is similar to their profile in the 2010 US Census [58]. Age-adjusted prevalence rates of hypertension, diabetes, overweight/obese BMI, current smoker, sedentary lifestyle, optimal daily consumption of fruits/vegetables, and weekly soda and fast food consumption varied significantly with duration of residence in the US (Fig. 1) [59].

In the unadjusted analyses, South Asian immigrants residing in the US for <15 years were less likely to self-

Table 2 Unadjusted logistic regression of CVD risk factors among South Asian adult immigrants in the 2005, 2007, and 2009 CHIS[a]

Outcome*	n	Duration of years in US, OR (95 % CI)				*p* value for linear trend
		0 to <5	5 to <10	10 to <15	15+	
Hypertension	1,158	**0.23 (0.11, 0.50)**	**0.37 (0.17, 0.79)**	**0.49 (0.27, 0.87)**	1	<0.001
High cholesterol	334	0.28 (0.07, 1.15)	0.57 (0.25, 1.31)	1.02 (0.37, 2.76)	1	0.03
Diabetes mellitus	1,025	1	0.37 (0.07, 1.98)	**0.49 (0.24, 0.97)**	1	<0.001
Overweight/obese	1,130	0.78 (0.47, 1.30)	**0.48 (0.28, 0.82)**	0.89 (0.56, 1.42)	1	0.03
Binge drinker	1,169	0.87 (0.15, 4.93)	2.21 (0.95, 5.14)	0.73 (0.30, 1.77)	1	0.22
Sedentary (no PA)	1,169	1.25 (0.63, 2.46)	0.64 (0.37, 1.10)	1.75 (1.00, 3.06)	1	0.85
Eats 5+ fruit/veg/day	1,169	**0.14 (0.03, 0.63)**	**0.25 (0.06, 0.97)**	**0.29 (0.11, 0.75)**	1	0.001
Drinks 4+ soda/week	1,169	2.22 (0.76, 4.45)	**4.24 (1.88, 9.54)**	1.51 (0.67, 3.40)	1	0.14
Eats 2+ fast food/week	794	**2.46 (1.20, 5.02)**	0.98 (0.45, 2.13)	0.88 (0.36, 2.17)	1	0.001

OR unadjusted odds ratio, *CI* confidence interval, *PA* physical activity

Bold, $p < 0.05$

[a] Current smoker—outcome did not vary across duration of residence in US categories; unable to perform analysis

report hypertension and eating five or more fruits and vegetables per day compared with those residing in the US for ≥15 years (Table 2). However, the mean daily intake of fruit/vegetable was 2.1 servings and the increased odds of consumption by duration of residence reflects small differences in overall consumption among South Asian immigrants (1.0 % of sample eat five or more fruits/vegetables daily for 0 to <5 years; 1.8 % for 5 to <10 years; 2.1 % for 10 to <15 years; 6.8 % for 15+ years). Increasing duration of residence was positively associated with self-reported diabetes and overweight/obesity, and negatively associated with fast food intake.

In the multivariate analyses, South Asian immigrants who resided in the US for 10 to <15 years had 2.11 greater odds (95 % CI 1.17, 3.81) of being sedentary and 0.37 lower odds (95 % CI 0.15, 0.94) of eating five or more fruits and vegetables per day compared to those who resided in the US for ≥15 years (Table 3), but a significant linear trend was found only for respondents' fruit and vegetable intake. More recent immigrants were also less likely to be overweight/obese than more settled South Asians (OR = 0.59 for 5 to <10 years; 95 % CI 0.35, 0.98). Results were unchanged in sensitivity analyses with different cut-points for BMI [60–64]. We found that South Asian immigrants who were overweight/obese had 2.32 greater odds (95 % CI 1.11, 4.86) of reporting diabetes and 2.19 greater odds (95 % CI 1.34, 3.56) of reporting hypertension than those with a healthy BMI. Similarly, immigrants who were sedentary had a 1.65 greater odds (95 % CI 1.15, 2.36) of being overweight/obese than those who were physically active.

Mean age at immigration increased linearly with duration of residence (Fig. 2), indicating that long-term South Asian residents (≥15 years of residence) immigrated to the US at older ages than more recent immigrants. Since prior research has shown a correlation between age at immigration to the US and some CVD risk factors [38, 42], we explored whether age at immigration moderated the association of duration of residence in the US with CVD risk factors through an interaction term. The interaction (years in the US ≥15 years * age at immigration) was significant for binge drinking ($p = 0.009$) and BMI ($p = 0.005$ as a continuous outcome).

Discussion

This is the first population-based study to examine the relationship between duration of residence in the US and multiple CVD risk factors specific to South Asian immigrants. We found that duration of residence in the US was significantly associated with overweight/obesity, which is consistent with previous studies that grouped South Asian immigrants with all foreign-born respondents or Asian foreign-born respondents [35, 36, 39–42]. We also found a positive association between duration of residence in the US and daily fruit and vegetable intake and physical activity, though the latter did not yield a significant linear trend. The increase in physical activity may be due to more leisure time and access to exercise facilities and/or adoption of health beliefs about the benefits of exercise as immigrants become acculturated [36]. For BMI, there was a significant interaction between age at immigration and duration of residence among South Asian immigrants; however, unlike the results described by Roshania et al. [42], the interaction did not remain significant when BMI was dichotomized into overweight/obese versus healthy BMI.

Table 3 Multivariate logistic regression of CVD risk factors among south Asian adult immigrants in CHIS 2005–2009, OR (95 % CI)[a]

	Hypertension n = 1,119	High cholesterol n = 325	Diabetes n = 991	Overwt/obese n = 1,130	Binge drinker n = 1,169	Sedentary n = 1,169	5 + fruit and veg/day n = 1,071	4 + soda/week n = 1,169	2 + fast food/week n = 794
Years in US									
0 to <5 years	0.79 (0.31, 2.00)	0.42 (0.10, 1.78)	1	0.84 (0.46, 1.53)	0.71 (0.11, 4.85)	1.84 (0.84, 4.00)	0.24 (0.04, 1.32)	1.33 (0.42, 4.21)	1.08 (0.47, 2.50)
5 to <10 years	1.05 (0.43, 2.55)	0.90 (0.32, 2.55)	0.81 (0.13, 5.09)	**0.59 (0.35, 0.98)**	1.12 (0.44, 2.88)	0.91 (0.50, 1.67)	0.36 (0.09, 1.45)	2.61 (0.97, 7.02)	0.60 (0.27, 1.34)
10 to <15 years	0.80 (0.38, 1.68)	1.69 (0.51, 5.57)	0.68 (0.27, 1.71)	0.83 (0.52, 1.33)	0.71 (0.27, 1.82)	**2.11 (1.17, 3.81)**	**0.37 (0.15, 0.94)**	1.18 (0.50, 2.79)	0.53 (0.19, 1.48)
15+ years	reference	reference	reference	reference	reference	reference	reference	reference	reference
Age at immigration	**1.08 (1.05, 1.10)**	**1.03 (1.00, 1.06)**	**1.06 (1.02, 1.09)**	1.00 (0.99, 1.02)	0.99 (0.96, 1.02)	1.01 (0.99, 1.03)	**1.03 (1.00, 1.06)**	**0.98 (0.94, 3.44)**	**0.93 (0.91, 0.96)**
Sex, male	**1.59 (1.07, 2.38)**	1.38 (0.63, 3.01)	**2.80 (1.39, 5.62)**	**1.53 (1.08, 2.18)**	**8.35 (3.60, 19.37)**	1.19 (0.78, 1.82)	**0.34 (0.18, 0.65)**	1.83 (0.98, 3.44)	1.53 (0.83, 2.82)
Married	1.66 (0.96, 2.87)	1.09 (0.34, 3.50)	2.01 (0.83, 4.86)	1.72 (0.98, 3.04)	**0.21 (0.08, 0.55)**	1.47 (0.79, 2.74)	0.85 (0.31, 2.33)	**0.32 (0.14, 0.72)**	1.34 (0.71, 2.53)
College or higher	1.32 (0.76, 2.30)	0.84 (0.29, 2.42)	1.67 (0.72, 3.84)	0.68 (0.41, 1.14)	1.24 (0.49, 3.15)	**0.55 (0.32, 0.95)**	2.08 (0.95, 4.58)	0.57 (0.27, 1.16)	0.81 (0.41, 1.62)
200+ % fpl	0.70 (0.30, 1.59)	4.73 (0.87, 25.82)	0.50 (0.16, 1.58)	0.87 (0.49, 1.52)	**3.20 (1.17, 8.77)**	1.04 (0.55, 1.96)	1.01 (0.27, 3.84)	1.58 (0.51, 4.94)	0.68 (0.30, 1.53)
Excellent/very good health	**0.58 (0.35, 0.96)**	0.67 (0.29, 1.53)	**0.20 (0.10, 0.41)**	**0.54 (0.38, 0.77)**	0.94 (0.45, 1.97)	**0.55 (0.35, 0.86)**	1.00 (0.41, 2.43)	0.76 (0.32, 1.79)	**0.35 (0.19, 0.62)**
Health insurance	1.08 (0.45, 2.60)	1.92 (0.43, 8.70)	0.24 (0.04, 1.46)	1.40 (0.75, 2.61)	1.46 (0.55, 3.87)	0.56 (0.28, 1.11)	1	**3.99 (1.50, 10.61)**	1.71 (0.78, 3.75)
Overwt/Obese	**2.19 (1.34, 3.56)**	1.30 (0.61, 2.80)	**2.32 (1.11, 4.86)**	x	x	x	x	x	x
Smoker	x	x	0.96 (0.26, 3.52)	1.08 (0.52, 2.25)	x	x	x	x	x
Binge drinker	0.67 (0.31, 1.46)	x	1.80 (0.54, 6.02)	0.89 (0.44, 1.83)	x	x	x	x	x
Sedentary	x	x	0.96 (0.42, 2.18)	**1.65 (1.15, 2.36)**	x	x	x	x	x
5+ fruits and veg per day	x	x	0.70 (0.19, 2.62)	1.25 (0.48, 3.22)	x	x	x	x	x

Of note, models with the dependent variable overweight/obese and 5+ fruit and veg/day had a significant linear trend for years in US ($p < 0.05$)

OR adjusted odds ratio, *CI* confidence interval, *x* not in model, *fpl* federal poverty level

Bold, $p < 0.05$

[a] Current smoker—outcome did not vary across duration of residence in US categories; unable to perform analysis

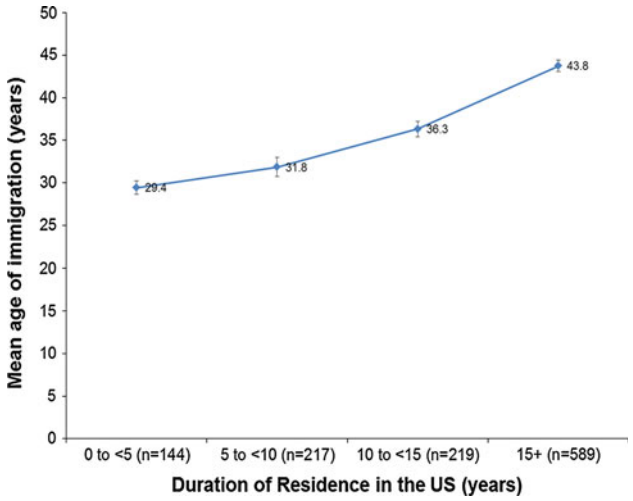

Fig. 2 Mean age at immigration by duration of residence in the US among South Asian adult immigrants in CHIS 2005–2009

Contrary to Koya and Egede's study in which multiple CVD risk factors were examined among all immigrant adults using the 2002 National Health Interview Survey, we did not find significant associations between duration of residence in the US and self-reported hyperlipidemia or smoking among South Asians [36]. We also found no association between duration of residence and diabetes or hypertension among South Asian immigrants, which is dissimilar to previous studies that combined national samples of foreign-born adults for analysis using self-reported measures [35, 38]. These differences between South Asians and other Asian immigrants indicate the value of examining Asian immigrant subgroups separately.

It is curious that South Asians immigrants would experience greater odds of being overweight or obese, but simultaneously be more likely to be physically active and eat more fruits and vegetables, with increasing duration of residence in the US Raj et al. [65] documented large increases in fruit juice intake with increasing duration in the US among Asian Indians, which may contribute to undesirable weight gain, though CHIS respondents were instructed not to include juices in their count of fruit and vegetable intake. One explanation may be that despite being less sedentary and eating more fruits and vegetables, long-term resident South Asian immigrants consume more calories than recent immigrants [65], which may offset the beneficial effects of physical activity and of certain recommended components of diet on BMI. Alternatively, as BMI increases with more years spent in the US, South Asian immigrants may try to curb the increased weight gain by eating a healthier diet and increasing physical activity. However, we found that physical activity and fruit and vegetable intake were not significant mediators of the relationship between duration of residence and overweight or obese BMI (analyses not shown). A longitudinal replication of the current study would clarify causal directions and thereby improve our understanding of the complex relationships between duration of residence, overweight/obesity, physical activity, and diet.

Our study has several limitations. The use of cross-sectional data impaired our ability to disentangle age and duration of residence effects as contributors to the effect of acculturation on CVD risk factors among South Asian immigrants. The response rates in CHIS were low, which might bias our results if responders and non-responders differed from each other with respect to CVD risk profiles and other characteristics. However, low survey response rates do not necessarily indicate a large amount of nonresponse error [66–70]. Data from self-report surveys may be inaccurate due to recall bias, social desirability bias, and respondents' lack of knowledge [71]. Some respondents may have been misclassified when assessing the prevalence of CVD risk factors. Self-reports of hypertension, hypercholesterolemia, and diabetes are likely related to one's access to health care, though we controlled statistically for variations in access to care by controlling for health insurance status and having a usual source of care. Furthermore, several studies have reported agreement between self-reported diabetes, hypertension, smoking, and alcohol consumption and medical record data or biochemical measures [72–75]. There is less agreement between self-reported high cholesterol and medical record data [76]. Survey respondents may have also underestimated weight, overestimated height, and under- or overestimated physical activity [77, 78]. Future research should also examine duration of residence in the US with more objective measures of CVD risk factors among South Asians, which may be available in newer datasets [79, 80].

Duration of residence in the US and age at immigration probably include some dimensions of acculturation, but do not fully capture this multidimensional construct. However, large, public-use datasets have few face-valid acculturation measures, and temporal measures have been used as proxies for acculturation in other studies [33]. We should note that some researchers have criticized the use of acculturation in health research given the conceptual and methodological difficulties, as well as its limitation as a modifiable factor in the promotion of cardiovascular health [81, 82]. Our study tried to control for modifiable factors, such as socioeconomic status and health insurance coverage. We also found a linear relationship between mean age at immigration and duration of residence in the US among South Asian adult immigrants, and future studies may examine generational differences in health beliefs and/or behaviors in these cohorts.

Duration of residence in the US appears to be an important determinant for CVD risk factors among South

Asian immigrants. Based on these findings, we recommend that interventions involving recent South Asian immigrants should focus on modifiable health behaviors, such as encouraging increased fresh fruit and vegetable consumption and physical activity to reduce the risk of obesity and CVD. South Asians would likely benefit from culturally tailored strategies to reduce obesity; further examination of physical activity and food choice practices in this community are particularly warranted.

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