ORIGINAL RESEARCH

Greater Acculturation is Associated With Poorer Cardiovascular Health in the Multi-Ethnic Study of Atherosclerosis

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BACKGROUND: Greater acculturation is associated with increased risk of cardiovascular disease. However, little is known about the association between acculturation and ideal cardiovascular health (CVH) as measured by the American Heart Association's 7 CVH metrics. We investigated the association between acculturation and ideal CVH among a multi-ethnic cohort of US adults free of clinical cardiovascular disease at baseline.

METHODS AND RESULTS: This was a cross-sectional analysis of 6506 men and women aged 45 to 84 years of 4 races/ethnicities. We examined measures of acculturation(birthplace, language spoken at home, and years lived in the United States [foreign-born participants]) by CVH score. Scores of 0 to 8 indicate inadequate, 9 to 10 average and 11 to 14 optimal CVH. We used multivariable regression to examine associations between acculturation and CVH, adjusting for age, sex, race/ethnicity, education, income and health insurance. The mean (SD) age was 62 (10) years, 53% were women, 39% non-Hispanic White-, 26% non-Hispanic Black-, 12% Chinese- and 22% Hispanic-Americans. US-born participants had lower odds of optimal CVH (odds ratio [OR]: 0.63 [0.50–0.79], $P<0.001$) compared with foreign-born participants. Participants who spoke Chinese and other foreign languages at home had greater odds of optimal CVH compared with those who spoke English (1.91 [1.08–3.36], $P=0.03$; and 1.65 [1.04–2.63], $P=0.03$, respectively). Foreign-born participants who lived the longest in the United States had lower odds of optimal CVH (0.62 [0.43–0.91], $P=0.02$).

CONCLUSIONS: Greater US acculturation was associated with poorer CVH. This finding suggests that the promotion of ideal CVH should be encouraged among immigrant populations since more years lived in the United States was associated with poorer CVH.

Key Words: acculturation ■ cardiovascular disease ■ ideal cardiovascular health metrics ■ Life's Simple 7 ■ risk factors

D espite being less acculturated, recent voluntary immigrants from minority ethnic groups have better health outcomes compared with native-born residents in the United States.[1–4] However, the health patterns of both populations become similar over time through the process of acculturation, which is defined as psychological, behavioral and attitudinal changes that occur when people from different cultures are in prolonged and direct contact with one another.[1,5,6] Most epidemiological studies show that greater US acculturation is positively associated with greater frequency of smoking, unhealthy diet, less physical activity, hypertension, diabetes mellitus and obesity.[7–9] Although in contrast, another study found that foreign-born non-Hispanic Asian adults who had lived in the United States for <15 years (ie, less US acculturation) had a higher prevalence of diabetes mellitus compared with US-born non-Hispanic Asian adults as well as foreign-born non-Hispanic Asian adults who had lived in the United States for 15 years or longer.[10] Thus, there

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CLINICAL PERSPECTIVE

What Is New?
- In this study, greater US acculturation was associated with poorer cardiovascular health in a multi-ethnic cohort of adult men and women free of cardiovascular disease at baseline.

What Are the Clinical Implications?
- The foreign-born population in the United States is expected to increase from 44 million in 2016 to 69 million in 2060 which translates to 1 in 5 people living in the United States.
- Therefore, promoting the achievement of ideal cardiovascular health among the US immigrant population has the potential to reduce the overall socioeconomic burden of cardiovascular disease.

Nonstandard Abbreviations and Acronyms

CVH   cardiovascular health
MESA Multi-Ethnic Study of Atherosclerosis

has been some inconsistencies in the prior literature about the impact of acculturation on cardiovascular health (CVH).

As part of the strategy to promote CVH and wellness, as well as to prevent and reduce cardiovascular disease (CVD) morbidity and mortality in the United States and globally, the American Heart Association recommends the use of 7 CVH metrics, known as "Life's Simple 7", as surveillance tools to accurately measure CVH and CVD mortality, incidence, and outcomes in the general population.[11–13] A person achieves ideal CVH by meeting specific criteria for 7 modifiable risk factors, which include smoking, body mass index (BMI), physical activity, diet, cholesterol, blood pressure and blood glucose.[11–13] Although prior studies have examined CVD risk factors among immigrant populations, research on the relationship between acculturation and the construct of ideal CVH is sparse and these studies assessed a single proxy measure of acculturation.[14–16]

Our aim is to explore the associations between proxy measures of acculturation (birthplace, language spoken at home and years lived in the United States) and CVH using data from the MESA (Multi-Ethnic Study of Atherosclerosis). Understanding these relationships may provide opportunities for targeted intervention and prevention strategies in efforts to improve CVH and further decrease CVD morbidity

and mortality among the diverse populations of the United States. Our study will test the hypothesis that greater US acculturation will be associated with less favorable CVH status.

METHODS

The data that support the findings of this study are available through the National Heart, Lung, Blood Institute Biologic Specimen and Data Repository Coordinating Center (BioLINCC). Requests for access to the data can be made through the website: https://biolincc.nhlbi.nih.gov/studies/mesa/.

Study Population

The MESA study methodology has been previously described.[17] Briefly, between July 2000 and August 2002, MESA recruited 6814 adult women and men between the ages of 45 and 84 years with no previous history of clinical CVD at baseline from 6 centers (Baltimore, MD; Chicago, IL; Forsyth County, NC; Los Angeles, CA; New York, NY and St Paul, MN) in the United States. MESA recruited study participants to investigate the characteristics of subclinical CVD and the risk factors that predict progression to clinical CVD. Among participants, 38% were non-Hispanic White, 12% Chinese American, 28% non-Hispanic Black and the remaining 22% were Hispanic. Each participant gave informed consent and the institutional review boards of all the recruitment centers approved the study protocol. MESA collected baseline information from participants using standardized questionnaires, physical examinations and fasting laboratory blood tests. The MESA questionnaires were available in English, Spanish and Chinese languages. For this study, we included 6506 participants from the baseline exam after excluding participants with missing information for the CVH metrics (n=308).

Independent Variable: Acculturation

Based on previous research, we selected 3 variables (birthplace, language spoken at home and number of years lived in the United States) from the baseline questionnaire as the proxy measures of acculturation.[18,19] These proxy measures are relatively simple to use within large studies without increasing participant burden. They characterize some of the major factors of acculturation and show strong correlations and high internal consistency with existing acculturation scales.[1,20] We assessed birthplace from the question "where were you born" and categorized it as US-born (within the 50 states of the United States) and foreign-born (including Puerto Rico). Language spoken at home was assessed by the question; "what language is generally spoken in your home",

and it was categorized as English, Spanish, Chinese and other foreign languages. Additionally, for foreign-born participants, we assessed years lived in the United States from the question; "how many years have you lived in the United States".

Dependent Variable: Cardiovascular Health

The American Heart Association defines ideal CVH as follows: non-smoking; BMI <25 kg/m^2; physical activity of 150 minutes/week for moderate exercise or 75 minutes/week for vigorous exercise; a healthy diet consistent with recommended dietary guidelines; total cholesterol <200 mg/dL (without lipid-lowering medications); blood pressure <120/<80 mm Hg (without anti-hypertensive medications) and fasting blood glucose <100 mg/dL (without anti-diabetic medications).[11] Self-report questionnaires were used to obtain information on smoking status defined as non-smokers (participants who reported they had never smoked or quit >12 months), former smokers (participants who quit within the past 12 months) and current smokers. We calculated BMI in kg/m^2 from the measured weights and heights of participants. MESA assessed physical activity from a self-report survey instrument that was adapted from the Cross-Cultural Activity Participation Study[21] containing 28 questions on time and frequency of activities during a week in the past month. The total minutes of moderate and vigorous exercise were estimated in metabolic equivalent of task per minute and

used in our study analysis.[22] MESA used a 120-item validated food frequency questionnaire modified from the Insulin Resistance Atherosclerosis Study instrument[23,24] to evaluate dietary habits. Components of a healthy diet based on recommended dietary guidelines include fruits and vegetables, fish, whole grains, intake of sodium <1500 mg/day and sugar-sweetened beverages ≤450 kcal (36 oz.)/week.[11] Total cholesterol (mg/dL) and blood glucose (mg/dL) levels were measured from blood samples collected after a 12-hour fast. MESA took 3 blood pressure readings from participants after 5 minutes of rest in a seated position and documented the mean of the last 2 readings.

Covariates

Baseline sociodemographic variables included as covariates in this study were age, sex, race/ethnicity, education, income and health insurance. We assessed age as a continuous variable and categorized sex into women and men. Race/ethnicity was classified as non-Hispanic White, Chinese-American, non-Hispanic Black and Hispanic. Education and income had 9 and 13 categories, respectively, but were presented as dichotomized variables in Table 1 while health insurance status was grouped into "Yes" and "No" responses.

Statistical Analysis

We reported the characteristics of study participants for the overall population and by the CVH score. We also reported frequencies with percentages for categorical

Table 1. Characteristics of Study Participants by Cardiovascular Health Score, MESA 2000 to 2002

	Total (N=6506)	Inadequate (n=3080)	Average (n=2120)	Optimal (n=1306)	*P* Value
Age, mean (SD), y	62 (10)	63 (10)	62 (11)	60 (10)	<0.001
Sex					
Men, n (%)	3074 (47%)	1465 (48%)	1002 (47%)	607 (46%)	0.80
Women, n (%)	3432 (53%)	1615 (52%)	1118 (53%)	699 (54%)	
Race/Ethnicity					
Non-Hispanic White, n (%)	2539 (39%)	980 (32%)	907 (43%)	652 (50%)	<0.001
Chinese American, n (%)	796 (12%)	216 (7%)	319 (15%)	261 (20%)	
Non-Hispanic Black, n (%)	1715 (26%)	1042 (34%)	474 (22%)	199 (15%)	
Hispanic, n (%)	1456 (22%)	842 (27%)	420 (20%)	194 (15%)	
Education					
≥ Bachelor's degree, n (%)	2331 (36%)	796 (26%)	834 (39%)	701 (54%)	<0.001
< Bachelor's degree, n (%)	4175 (64%)	2284 (74%)	1286 (61%)	605 (46%)	
Income					
≥$40 000, n (%)	3214 (49%)	1272 (41%)	1125 (53%)	817 (63%)	<0.001
<$40 000, n (%)	3292 (51%)	1808 (59%)	995 (47%)	489 (37%)	
Health insurance					
Yes, n (%)	5925 (91%)	2792 (91%)	1945 (92%)	1188 (91%)	0.39
No, n (%)	581 (9%)	288 (9%)	175 (8%)	118 (9%)	

Cardiovascular health score ranges from 0 to 14; inadequate score, 0 to 8; average, 9 to 10; optimal, 11 to 14. Percentages (%) rounded up to whole numbers. MESA indicates Multi-Ethnic Study of Atherosclerosis.

variables and means with SD for continuous variables. We used the Chi-square and ANOVA tests to compare baseline characteristics of participants by the CVH score for categorical and continuous variables, respectively. We categorized each CVH metric into poor, intermediate and ideal as presented in Table S1.[11] We assigned points to the categories as follows: 0 points for poor, 1 point for intermediate and 2 points for ideal giving a total CVH score that ranged from 0 to 14.[25] Based on previous studies, the CVH score was further categorized as inadequate (0–8), average (9–10) and optimal (11–14).[22,26–29]

We reported the proportions of each category of the CVH metrics by the measures of acculturation (i.e., birthplace, language spoken at home and years lived in the United States). We estimated the associations between the measures of acculturation and the CVH score using multinomial logistic regression. We fitted 2 separate models. Model 1 was unadjusted and we adjusted model 2 for sociodemographic factors (age, sex, race/ethnicity, education [9 categories], income [13 categories] and health insurance status). We reported the odds ratios (ORs) and the corresponding 95% CI for the average and optimal CVH scores. The reference groups were the "inadequate score" for the CVH score, "foreign-born" for birthplace, "English" for language spoken at home and "tertile 1" for years lived in the United States. We tested for effect modification by age (<65 versus ≥65 years), sex and race/ethnicity by inserting interaction terms in model 2. In addition, we estimated the associations between the measures of acculturation and the CVH metrics using multinomial logistic regression adjusting for sociodemographic factors. The reference group was the "poor metric" for the CVH metrics. Furthermore, in supplemental analysis, we examined the associations of the number of generations in the United States (a proxy measure of acculturation)[18] with the CVH score and metrics. Generation was coded as: 0 (foreign-born), first (one or both parents foreign-born), second (both parents US-born and at least 2 grandparents foreign-born) and third (both parents and 3 or more grandparents US-born).[18] STATA version 15.0 (StataCorp LP, College Station, TX) was used for all statistical analyses and a 2-sided alpha level of <0.05 was considered statistically significant.

RESULTS

Most of the baseline characteristics of study participants (N=6506) varied by the categories of the CVH score as reported in Table 1. The mean age (SD) of participants was 62 (10) years and 53% were women. The mean (SD) of the CVH score by the measures acculturation are as follows: birthplace(US-born, 8.5 [2.2]; foreign-born, 8.8 [2.2]), language spoken at home (English, 8.5 [2.2]; Spanish, 8.0 [2.2]; Chinese, 9.6 [1.9]; Other, 9.3 [2.1]) and years lived in

the US (tertile 1, 9.2 [2.0]; tertile 2, 8.8 [2.3]; tertile 3, 8.3 [2.2]). As illustrated in the Figure 1, US-born participants had a higher proportion with inadequate CVH scores compared with foreign-born participants (49% versus 44%). Participants who spoke English or Spanish as the primary language at home had the highest proportion with inadequate CVH scores and the lowest proportion with optimal CVH scores (48% versus 59% for inadequate scores and 19% versus 13% for optimal scores, respectively). Participants who had lived the longest in the United States (tertile 3) had the highest proportion with inadequate scores and the lowest proportion with optimal scores (54% and 18%, respectively).
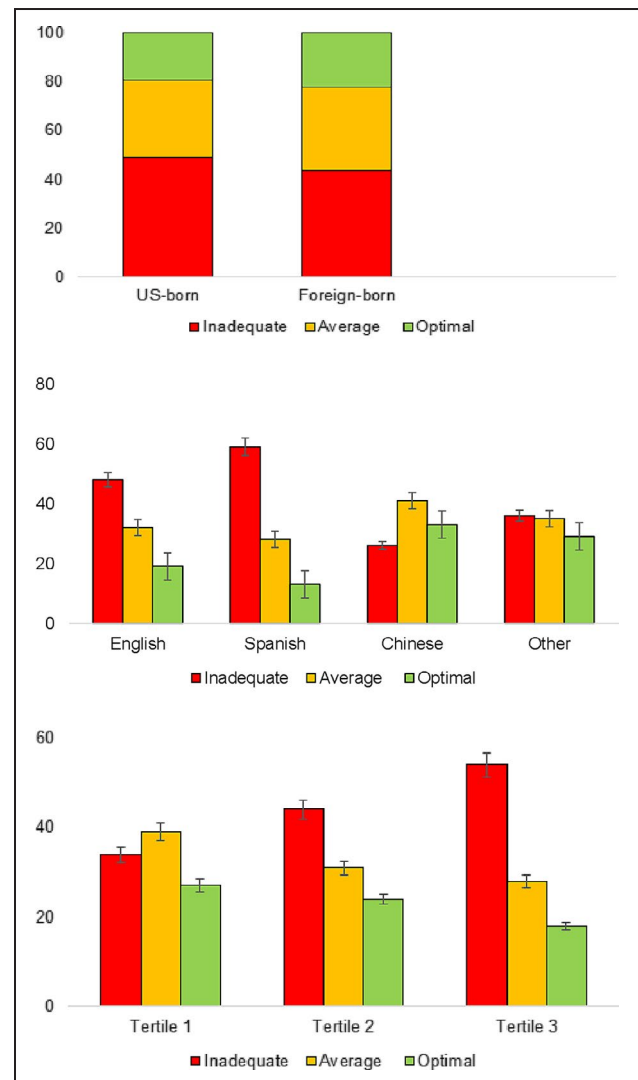

Figure 1. Percentage distribution of the cardiovascular health score by measures of acculturation (birthplace, language spoken at home and years lived in the United States, tertiles 1–3).
Red: inadequate (0–8 points); Orange: average (9–10 points); and Green: optimal (11–14 points). Error bars on the bar graphs represent percentage error.

Table 2. Distribution of CVH Metrics by Measures of Acculturation

	Birthplace		Language Spoken at Home				Years Lived in the United States
	US-Born (n=4413)	Foreign-Born (n=2093)	English (n=4621)	Spanish (n=1036)	Chinese (n=640)	Other (n=209)	Foreign-Born (n=1855)*
Smoking							
Poor	634 (14%)	205 (10%)	651 (14%)	135 (13%)	36 (6%)	17 (8%)	27 (14–38)
Intermediate	58 (1%)	22 (1%)	62 (1%)	12 (1%)	4 (1%)	2 (1%)	21 (14–43)
Ideal	3721 (84%)	1866 (89%)	3908 (85%)	889 (86%)	600 (94%)	190 (91%)	25 (15–36)
Body mass index							
Poor	1588 (36%)	485 (23%)	1648 (36%)	367 (35%)	24 (4%)	34 (16%)	30 (20–40)
Intermediate	1727 (39%)	831 (40%)	1802 (39%)	486 (47%)	194 (30%)	76 (36%)	28 (15–38)
Ideal	1098 (25%)	777 (37%)	1171 (25%)	183 (18%)	422 (66%)	99 (47%)	21 (12–31)
Physical activity							
Poor	871 (20%)	615 (29%)	917 (20%)	353 (34%)	167 (26%)	49 (23%)	25 (15–35)
Intermediate	760 (17%)	368 (18%)	787 (17%)	183 (18%)	123 (19%)	35 (17%)	23 (14–35)
Ideal	2782 (63%)	1110 (53%)	2917 (63%)	500 (48%)	350 (55%)	125 (60%)	27 (15–37)
Diet							
Poor	2154 (49%)	789 (38%)	2205 (48%)	511 (49%)	162 (25%)	65 (31%)	27 (16–37)
Intermediate	2215 (50%)	1278 (61%)	2367 (51%)	516 (50%)	467 (73%)	143 (68%)	24 (14–36)
Ideal	44 (1%)	26 (1%)	49 (1%)	9 (1%)	11 (2%)	1 (0.5%)	32 (22–36)
Total cholesterol							
Poor	571 (13%)	301 (14%)	603 (13%)	180 (17%)	65 (10%)	24 (11%)	30 (17–38)
Intermediate	1793 (41%)	751 (36%)	1862 (40%)	366 (35%)	231 (36%)	85 (41%)	27 (15–38)
Ideal	2049 (46%)	1041 (50%)	2156 (47%)	490 (47%)	344 (54%)	100 (48%)	24 (13–35)
Blood pressure							
Poor	1717 (39%)	722 (35%)	1773 (38%)	383 (37%)	219 (34%)	64 (31%)	30 (16–39)
Intermediate	1239 (28%)	580 (28%)	1318 (29%)	285 (28%)	161 (25%)	55 (26%)	26 (16–37)
Ideal	1457 (33%)	791 (38%)	1530 (33%)	368 (36%)	260 (41%)	90 (43%)	22 (13–33)
Blood glucose							
Poor	434 (10%)	266 (13%)	435 (9%)	167 (16%)	77 (12%)	21 (10%)	28 (16–40)
Intermediate	619 (14%)	368 (18%)	651 (14%)	175 (17%)	116 (18%)	45 (22%)	28 (16–36)
Ideal	3360 (76%)	1459 (70%)	3535 (77%)	694 (67%)	447 (70%)	143 (68%)	25 (14–35)

Percentages (%) rounded up to whole numbers. CVH indicates cardiovascular health.
*1855 foreign-born participants had data for number of years lived in the United States.

Table 2 shows the distribution of the CVH metrics by the measures of acculturation. Majority of participants regardless of birthplace or language spoken at home met the ideal criteria for smoking, physical activity, total cholesterol and blood glucose. A quarter of US-born and over a third of foreign-born participants met the ideal criteria for BMI. Participants who spoke English or Spanish at home had the lowest proportion in the ideal category of BMI. Between one half and 2 percent of participants met the ideal criteria for diet regardless of birthplace or language spoken at home. About a third or more of the participants were in the ideal category of blood pressure irrespective of birthplace or language spoken at home. Participants with the highest median number of years lived in the United States were in the poor categories of smoking, BMI, total cholesterol and blood pressure. However, participants with the highest median number of years lived in the United States were in the ideal categories for physical activity and diet.

Table 3 shows the multivariable-adjusted associations between acculturation and the CVH score. US-born participants had lower odds of having average and optimal CVH scores compared with foreign-born participants (ORs, 0.80 [95% CI, 0.66–0.96] and 0.63 [0.50–0.79], respectively). For languages spoken at home, participants who spoke Chinese and other foreign languages had greater odds of having optimal CVH scores (1.91 [1.08–3.36] and 1.65 [1.04–2.63], respectively) compared with those who spoke English at home. Participants who had lived the longest in the United States (tertile 3) had lower odds of having average and optimal CVH scores (0.58 [0.42–0.80] and 0.62 [0.43–0.91]), respectively.

Table 4 shows the multivariable-adjusted associations between acculturation and the individual CVH metrics. US-born participants had lowers odd of ideal smoking, BMI, diet and blood pressure compared with foreign-born participants (ORs, 0.65 [0.51–0.84], 0.59 [0.47–0.74], 0.30 [0.14–0.60], 0.80 [0.65–0.99], respectively). In contrast, US-born participants had greater odds of ideal physical activity compared with foreign-born participants (1.22 [1.01–1.49]). Participants who spoke Spanish, Chinese and other foreign languages at home had greater odds of ideal BMI (1.56 [1.12–2.17], 3.03 [1.35–6.80], 1.66 [1.01–2.70]), respectively, compared with those who spoke English at home. In addition, those who spoke Spanish at home had greater odds of ideal diet (5.47 [1.19–25.20]) while those who spoke other foreign languages at home had greater odds of ideal blood pressure (1.80 [1.14–2.83]). Participants who had lived the longest in the United States (tertile 3) had lower odds of ideal BMI (0.57 [0.37–0.86]) and ideal blood pressure (0.66 [0.47–0.94]).

We found that age modified the association between 2 of the independent variables (birthplace and years lived in the United States) and CVH with

P<0.05. However, there was no meaningful interaction by sex and race/ethnicity. Among participants aged <65 years, US-born and those who had lived the longest in the United States had lower odds of optimal CVH scores (ORs, 0.58 [0.44–0.78] and 0.39 [0.24–0.63], respectively) (Table S2). Tables S3 through S5 and Figure S1 examine the associations of the number of generations in the United States with the CVH score and metrics. In comparison with participants who were considered 0 generations in the United States, participants who were second and third generations had lower odds of having optimal CVH scores (0.63 [0.47–0.84] and 0.51 [0.40–0.66], respectively). Participants who were third generation had lower odds of ideal smoking, BMI, diet, blood pressure and blood glucose (Table S5).

DISCUSSION

In this cross-sectional analysis of 6506 adults free of clinical CVD at baseline, after adjusting for sociodemographic factors, we found that US-born participants had lower odds of having average and optimal CVH scores compared with foreign-born participants. Participants who spoke Chinese or other foreign languages at home had greater odds of having optimal CVH scores compared with participants who spoke English. In addition, we found that participants who had lived the longest in the United States had lower odds of having average and optimal CVH scores.

A few other studies using different populations have examined the association between measures of acculturation and the CVH metrics. For example, a cross-sectional study of Asian Americans and Latinos using the National Health and Nutrition Examination Survey from 2011 to 2016 examined the association of language spoken at home with the metrics of smoking, blood pressure, glucose and total cholesterol. The authors found that after adjusting for age, sex, education and income, participants who spoke their native languages at home had a lower prevalence of the poor/intermediate category of smoking and blood pressure compared with those who spoke English at home(prevalence ratios: Asian Americans, 0.60 [0.45–0.81] and 0.83 [0.75–0.92]; Latinos, 0.56 [0.47–0.68] and 0.86 [0.80–0.93], respectively).[14] These findings are comparable with the findings of our study where participants who spoke other foreign languages at home had greater odds of ideal blood pressure compared with those who spoke English at home (1.80 [1.14–2.83]).

Another cross-sectional study examined the length of residence in the United States and CVH among Afro-Caribbean immigrants in New York City using a community health survey from 2011 to 2014. The study found that after adjusting for age, sex, education, employment, insurance status and healthcare access,

Table 3. Multivariable-Adjusted Associations Between Acculturation and Cardiovascular Health Score

	Average vs Inadequate	Optimal vs Inadequate	Average vs Inadequate	Optimal vs Inadequate
	Model 1		Model 2	
	OR (95% CI)		OR (95% CI)	
Birthplace				
Foreign-born	Reference	Reference	Reference	Reference
US-born	0.86 (0.76–0.97)*	0.76 (0.66–0.87)*	0.80 (0.66–0.96)*	0.63 (0.50–0.79)*
Language spoken at home				
English	Reference	Reference	Reference	Reference
Spanish	0.70 (0.60–0.81)*	0.57 (0.46–0.69)*	1.00 (0.77–1.29)	1.38 (0.98–1.94)
Chinese	2.31 (1.88–2.83)*	3.12 (2.51–3.88)*	1.65 (0.97–2.80)	1.91 (1.08–3.36)*
Other	1.47 (1.06–2.03)*	1.99 (1.40–2.82)*	1.27 (0.84–1.94)	1.65 (1.04–2.63)*
Years lived in the United States[†]				
Tertile 1	Reference	Reference	Reference	Reference
Tertile 2	0.62 (0.48–0.81)*	0.71 (0.54–0.94)*	0.71 (0.53–0.94)*	0.87 (0.63–1.20)
Tertile 3	0.47 (0.36–0.60)*	0.43 (0.32–0.57)*	0.58 (0.42–0.80)*	0.62 (0.43–0.91)*

Model 1: unadjusted. Model 2: adjusted for age, sex, race/ethnicity, education, income and health insurance. Cardiovascular health score ranges from 0 to 14; inadequate score, 0 to 8; average, 9 to 10; optimal, 11 to 14. Other indicates other foreign languages spoken at home. Interaction by age was significant for birthplace and years lived in the United States at $P<0.05$. OR indicates odds ratio.

*denotes statistically significant results at $P<0.05$.

[†]Years lived in the United States for foreign-born participants, n=1855.

immigrants of Guyanese and Haitian origin who had lived in the United States for ≥10 years had higher prevalence odds of the poor/intermediate category of the CVH score compared with those who had lived in the United States for <10 years (ORs: 3.51 [1.03–11.95] and 8.02 [1.88–34.12], respectively).[16] Similarly, our study found that participants who had lived the longest in the United States had lower CVH scores. Another study from the Hispanic Community Health Study/Study of Latinos found that among various measures of acculturation, the length of residency in mainland United States was the strongest predictor of moderate and extreme obesity.[9] We also found that our study participants who had lived in the United States for the greatest number of years were less likely to have ideal BMI of <25 kg/m^2.

Lastly, a cross-sectional analysis of 15 965 adults from the 2011 to 2016 National Health and Nutrition Examination Survey examined the associations between nativity/length of residence in the United States and CVD risk factors.[10] The authors found that in sex-, age-, education-, race- and Hispanic origin- adjusted analyses, a greater proportion of US-born adults had ≥1 CVD risk factor compared with non-US born adults (US-born, 86.6%; versus non-US born ≥15 years in United States, 85.1%; versus non-US born <15 years in United States, 80.1%). Non-US born adults had a lower prevalence ratio of hypertension and overweight/obesity compared with US-born adults (hypertension: non-US born ≥15 years in United States, 0.89 [0.83–0.96]; non-US born <15 years in United States, 0.79 [0.72–0.87]; overweight/obesity: non-US born <15 years, 0.92 [0.88–0.97]). Comparably, our results

showed that US-born and foreign-born participants (who had lived the longest in the United States) had lower odds of ideal blood pressure and BMI.

Our study adds to this growing body of literature by investigating these relationships in a well-characterized diverse population consisting of 4 racial/ethnic groups who were free of CVD at baseline. We assessed additional measures of acculturation including generational status. The findings of our study and the other studies described above may be explained by the healthier lifestyles of foreign-born participants compared with US-born participants. For example, in 2016, the prevalence of obesity among US adults was ≈36% compared with 6%, 28% and 29% among adults in China, Dominican Republic and Mexico, respectively.[30] Study participants born in these 3 countries made up a larger proportion of our study population. The higher prevalence of obesity among US adults is most likely driven by poorer dietary patterns of high calorie and sodium intake representative of the typical American diet, which may also be responsible for the higher blood pressure levels. However, foreign-born participants were less likely to meet the recommendations for ideal physical activity compared with US-born participants. This may be due to several factors that include cultural dispositions towards physical activity[31] as well as socioeconomic barriers that limit access to fitness facilities and safe recreational areas.[32] In addition, foreign-born participants who had lived the longest in the United States were more likely to have poorer CVH, and in particular, lower odds of ideal BMI and blood pressure. The process of acculturation may explain these findings. Greater acculturation is associated with health-reducing

Table 4. Multivariable-Adjusted Associations Between Acculturation and the CVH Metrics

	Smoking		Body Mass Index		Physical Activity		Diet	
	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor
	OR (95% CI)		OR (95% CI)		OR (95% CI)		OR (95% CI)	
Birthplace								
Foreign-born	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
US-born	0.67 (0.32–1.40)	0.65 (0.51–0.84)*	0.69 (0.57–0.84)*	0.59 (0.47–0.74)*	1.25 (0.97–1.62)	1.22 (1.01–1.49)*	0.57 (0.48–0.67)*	0.30 (0.14–0.60)*
Language spoken at home								
English	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Spanish	0.74 (0.28–2.01)	1.28 (0.91–1.81)	1.57 (1.21–2.04)*	1.56 (1.12–2.17)*	0.99 (0.69–1.43)	0.75 (0.57–0.99)*	1.34 (1.06–1.70)*	5.47 (1.19–25.20)*
Chinese	...	1.44 (0.62–3.38)	2.03 (0.89–4.64)	3.03 (1.35–6.80)*	0.81 (0.41–1.63)	0.89 (0.51–1.55)	1.89 (1.18–3.02)*	...
Other	2.07 (0.44–9.69)	1.49 (0.82–2.71)	1.34 (0.84–2.15)	1.66 (1.01–2.70)*	0.81 (0.45–1.45)	1.01 (0.64–1.59)	1.80 (1.24–2.61)*	1.39 (0.17–11.19)
Years lived in the United States								
Tertile 1	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.33 (0.09–1.29)	1.11 (0.74–1.68)	0.79 (0.56–1.12)	0.82 (0.57–1.20)	0.83 (0.59–1.18)	0.96 (0.73–1.27)	0.89 (0.69–1.15)	3.04 (0.83–11.19)
Tertile 3	0.55 (0.13–2.29)	1.06 (0.66–1.69)	0.97 (0.67–1.40)	0.57 (0.37–0.86)*	1.02 (0.68–1.53)	0.99 (0.72–1.37)	0.80 (0.60–1.07)	3.08 (0.70–13.60)

	Total Cholesterol		Blood Pressure		Blood Glucose	
	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor	Intermediate vs Poor	Ideal vs Poor
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
Birthplace						
Foreign-born	Reference	Reference	Reference	Reference	Reference	Reference
US-born	1.19 (0.92–1.52)	1.09 (0.86–1.39)	0.79 (0.64–0.97)*	0.80 (0.65–0.99)*	0.75 (0.55–1.03)	0.77 (0.60–1.00)
Language spoken at home						
English	Reference	Reference	Reference	Reference	Reference	Reference
Spanish	0.94 (0.66–1.32)	0.98 (0.70–1.37)	1.06 (0.79–1.42)	1.11 (0.83–1.48)	0.95 (0.63–1.42)	1.17 (0.84–1.64)
Chinese	0.92 (0.43–1.96)	1.05 (0.50–2.20)	1.08 (0.61–1.92)	1.55 (0.89–2.67)	0.77 (0.31–1.91)	0.61 (0.28–1.35)
Other	1.06 (0.59–1.90)	1.01 (0.57–1.79)	1.23 (0.76–1.99)	1.80 (1.14–2.83)*	1.27 (0.63–2.57)	0.77 (0.41–1.44)
Years lived in the United States						
Tertile 1	Reference	Reference	Reference	Reference	Reference	Reference
Tertile 2	0.88 (0.60–1.31)	0.81 (0.55–1.17)	0.78 (0.57–1.07)	0.69 (0.51–0.94)*	1.00 (0.64–1.56)	0.86 (0.59–1.26)
Tertile 3	0.92 (0.60–1.42)	0.71 (0.47–1.07)	0.74 (0.52–1.04)	0.66 (0.47–0.94)*	0.91 (0.55–1.50)	0.70 (0.46–1.06)

–, odds ratios were not reported because of the small sample sizes. CVH indicates cardiovascular health; and OR, odds ratio.
*denotes statistically significant results at P<0.05.

behaviors such as a decrease in fruit and vegetable consumption,[1,33] which may lead to an increase in the prevalence of CVD risk factors.

According to projections from the US Census Bureau, the foreign-born population in the United States is expected to rise from 44 million people in 2016 to 69 million in 2060, a significant increase from 14% to 17% of the overall US population.[34] The findings of this study underscore the importance of promoting CVH and wellness in the US immigrant population since ≈1 in 5 people living in the United States will be foreign-born in a few decades. Our study highlights the role acculturation may play in worsening CVH since foreign-born participants who had lived the longest in the United States had less favorable CVH. Furthermore, since recent migrants are in better health compared with the native-born residents of their host country, community-based health intervention programs targeting recent migrants should be designed to promote the retention of original healthy behaviors and discourage the adoption of unhealthy behaviors that may worsen CVH.[35–37] Additionally, the annual direct and indirect cost of CVD was estimated at $550 billion in 2015 accounting for 17% of the total healthcare expenditure.[38,39] This estimate is projected to increase to ≈$1.1 trillion by 2035.[38] Therefore, maintaining healthy lifestyles among recent migrants may contribute to curtailing the rising healthcare costs attributable to CVD in the United States.

The strengths of our study include the use of a multi-ethnic sample of US adults and the availability of data on several proxy measures of acculturation. However, some limitations should be considered in the interpretation of our findings. First, we cannot make causal inferences or determine temporality because of the cross-sectional study design. Second, in this study, we evaluated 3 established proxy measures of acculturation, which have been examined in other studies.[18,19,40] However, the process of acculturation is complex and no single measure can accurately capture it in its entirety. Other measures of acculturation or summary scores of acculturations, which were not examined here, may also correlate with CVH. Of note, prior studies have demonstrated that the multidimensional acculturation scales strongly correlate with proxy measures of acculturations such as years lived in the United States with correlation coefficients of 0.6 to 0.8.[41,42] Third, the metrics of smoking, diet and physical activity were self-reported and may be subject to recall bias. Fourth, the administered MESA questionnaires were available in English, Spanish and Chinese, but not in other foreign languages. Fifth, the CVH status assessed at baseline may not be representative of the future CVH status of the study participants. Finally, our findings may not be generalizable to adults outside the ages of 45 to 84 years and to all adults of Hispanic origin because of the substantial heterogeneity of the population.[7,43] Therefore, new studies may be required to examine the association between acculturation and ideal CVH by subpopulations of Hispanic ethnicity.

CONCLUSIONS

Greater US acculturation was associated with poorer CVH. This finding suggests that the promotion of ideal CVH should be encouraged among immigrant populations since greater number of years lived in the United States was associated with lower CVH scores. Future research may be required to investigate how the process of acculturation may worsen or improve CVH. In addition, understanding the relationship between acculturation and CVH may facilitate the development of culturally tailored programs that promote CVH and wellness among immigrant populations.

REFERENCES

1. Alidu L, Grunfeld EA. A systematic review of acculturation, obesity and health behaviours among migrants to high-income countries. *Psychol Health*. 2018;33:724–745. DOI: 10.1080/08870446.2017.1398327.

2. Dey AN, Lucas JW. Physical and mental health characteristics of U.S.- and foreign-born adults: United States, 1998–2003. *Adv Data*. 2006;369:1–19.

3. Markides KS, Eschbach K. Aging, migration, and mortality: current status of research on the Hispanic paradox. *J Gerontol B Psychol Sci Soc Sci*. 2005;60(Spec No 2):68–75. DOI: 10.1093/geronb/60. Special_Issue_2.S68.

4. Turkson-Ocran RN, Nmezi NA, Botchway MO, Szanton SL, Golden SH, Cooper LA, Commodore-Mensah Y. Comparison of cardiovascular disease risk factors among African immigrants and African Americans: an analysis of the 2010 to 2016 National Health Interview Surveys. *J Am Heart Assoc*. 2020;9:e013220. DOI: 10.1161/JAHA.119.013220.

5. Goel MS, McCarthy EP, Phillips RS, Wee CC. Obesity among US immigrant subgroups by duration of residence. *JAMA*. 2004;292:2860–2867. DOI: 10.1001/jama.292.23.2860.

6. Berry JW. Immigration, acculturation, and adaptation. *Appl Psychol*. 1997;46:5–34. DOI: 10.1111/j.1464-0597.1997.tb01087.x.

7. Rodriguez F, Hastings KG, Hu J, Lopez L, Cullen M, Harrington RA, Palaniappan LP. Nativity status and cardiovascular disease mortality among Hispanic adults. *J Am Heart Assoc*. 2017;6:e007207. DOI: 10.1161/JAHA.117.007207.

8. Commodore-Mensah Y, Ukonu N, Cooper LA, Agyemang C, Himmelfarb CD. The association between acculturation and cardiovascular disease risk in Ghanaian and Nigerian-born African immigrants in the United States: the Afro-Cardiac Study. *J Immigr Minor Health*. 2018;20:1137–1146. DOI: 10.1007/s10903-017-0644-y.

9. Isasi CR, Ayala GX, Sotres-Alvarez D, Madanat H, Penedo F, Loria CM, Elder JP, Daviglus ML, Barnhart J, Siega-Riz AM, et al. Is acculturation related to obesity in Hispanic/Latino adults? Results from the Hispanic community health study/study of Latinos. *J Obes*. 2015;2015:186276. DOI: 10.1155/2015/186276.

10. Fryar CD, Fakhouri TH, Carroll MD, Frenk SM, Ogden CL. The association of nativity/length of residence and cardiovascular disease risk factors in the United States. *Prev Med*. 2020;130:105893. DOI: 10.1016/j.ypmed.2019.105893.

11. Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, Greenlund K, Daniels S, Nichol G, Tomaselli GF, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. *Circulation*. 2010;121:586–613. DOI: 10.1161/CIRCULATIONAHA.109.192703.

12. Angell SY, McConnell MV, Anderson CAM, Bibbins-Domingo K, Boyle DS, Capewell S, Ezzati M, de Ferranti S, Gaskin DJ, Goetzel RZ, et al. The American Heart Association 2030 impact goal: a presidential advisory from the American Heart Association. *Circulation*. 2020;141:e120–e138. DOI: 10.1161/CIR.0000000000000758.

13. Roger VL, Sidney S, Fairchild AL, Howard VJ, Labarthe DR, Shay CM, Tiner AC, Whitsel LP, Rosamond WD. Recommendations for cardiovascular health and disease surveillance for 2030 and beyond: a policy statement from the American Heart Association. *Circulation*. 2020;141:e104–e119. DOI: 10.1161/CIR.0000000000000756.

14. Rodriguez F, Echeverria SE, Pentakota SR, Amadi C, Hastings KG, Palaniappan LP. Comparison of ideal cardiovascular health attainment and acculturation among Asian Americans and Latinos. *Ethn Dis*. 2019;29:287–296. DOI: 10.18865/ed.29.2.287.

15. Brown AF, Liang LJ, Vassar SD, Escarce JJ, Merkin SS, Cheng E, Richards A, Seeman T, Longstreth WT Jr. Trends in racial/ethnic and nativity disparities in cardiovascular health among adults without prevalent cardiovascular disease in the United States, 1988 to 2014. *Ann Intern Med*. 2018;168:541–549. DOI: 10.7326/M17-0996.

16. Thomas SC, Umer A, Commodore-Mensah Y, Davidov D, Abildso CG. Length of residence and cardiovascular health among Afro-Caribbean immigrants in New York City. *J Racial Ethn Health Disparities*. 2019;6:487–496. DOI: 10.1007/s40615-018-00547-8.

17. Bild DE, Bluemke DA, Burke GL, Detrano R, Diez Roux AV, Folsom AR, Greenland P, Jacob DR Jr, Kronmal R, Liu K, et al. Multi-Ethnic Study of Atherosclerosis: objectives and design. *Am J Epidemiol*. 2002;156:871–881. DOI: 10.1093/aje/kwf113.

18. Diez Roux AV, Detrano R, Jackson S, Jacobs DR Jr, Schreiner PJ, Shea S, Szklo M. Acculturation and socioeconomic position as predictors of coronary calcification in a multiethnic sample. *Circulation*. 2005;112:1557–1565. DOI: 10.1161/CIRCULATIONAHA.104.530147.

19. Effoe VS, Chen H, Moran A, Bertoni AG, Bluemke DA, Seeman T, Darwin C, Watson KE, Rodriguez CJ. Acculturation is associated with left ventricular mass in a multiethnic sample: the Multi-Ethnic Study of Atherosclerosis. *BMC Cardiovasc Disord*. 2015;15:161. DOI: 10.1186/s12872-015-0157-3.

20. Cruz TH, Marshall SW, Bowling JM, Villaveces A. The validity of a proxy acculturation scale among U.S. Hispanics. *Hisp J Behav Sci*. 2008;30:425–446. DOI: 10.1177/0739986308323653.

21. Ainsworth BE, Irwin ML, Addy CL, Whitt MC, Stolarczyk LM. Moderate physical activity patterns of minority women: the Cross-Cultural Activity Participation Study. *J Womens Health Gend Based Med*. 1999;8:805–813. DOI: 10.1089/152460999319129.

22. Unger E, Diez-Roux AV, Lloyd-Jones DM, Mujahid MS, Nettleton JA, Bertoni A, Badon SE, Ning H, Allen NB. Association of neighborhood characteristics with cardiovascular health in the Multi-Ethnic Study of Atherosclerosis. *Circ Cardiovasc Qual Outcomes*. 2014;7:524–531. DOI: 10.1161/CIRCOUTCOMES.113.000698.

23. Block G, Woods M, Potosky A, Clifford C. Validation of a self-administered diet history questionnaire using multiple diet records. *J Clin Epidemiol*. 1990;43:1327–1335. DOI: 10.1016/0895-4356(90)90099-B.

24. Mayer-Davis EJ, Vitolins MZ, Carmichael SL, Hemphill S, Tsaroucha G, Rushing J, Levin S. Validity and reproducibility of a food frequency interview in a Multi-Cultural Epidemiology Study. *Ann Epidemiol*. 1999;9:314–324. DOI: 10.1016/s1047-2797(98)00070-2.

25. Lloyd-Jones DM. Improving the cardiovascular health of the US population. *JAMA*. 2012;307:1314–1316. DOI: 10.1001/jama.2012.361.

26. Osibogun O, Ogunmoroti O, Tibuakuu M, Benson EM, Michos ED. Sex differences in the association between ideal cardiovascular health and biomarkers of cardiovascular disease among adults in the United States: a cross-sectional analysis from the Multiethnic Study of Atherosclerosis. *BMJ Open*. 2019;9:e031414. DOI: 10.1136/bmjopen-2019-031414.

27. Ogunmoroti O, Utuama OA, Michos ED, Valero-Elizondo J, Okunrintemi V, Taleb ZB, Bahelah R, Das S, Rouseff M, Parris D, et al. Does education modify the effect of ethnicity in the expression of ideal cardiovascular health? The Baptist Health South Florida Employee Study. *Clin Cardiol*. 2017;40:1000–1007. DOI: 10.1002/clc.22757.

28. Ogunmoroti O, Utuama OA, Salami JA, Valero-Elizondo J, Spatz ES, Rouseff M, Parris D, Das S, Guzman H, Agatston A, et al. Association between self-rated health and ideal cardiovascular health: the Baptist Health South Florida Employee Study. *J Public Health*. 2018;40:e456–e463. DOI: 10.1093/pubmed/fdx140.

29. Ogunmoroti O, Osibogun O, Kolade OB, Ying W, Sharma G, Vaidya D, Michos ED. Multiparity is associated with poorer cardiovascular health among women from the Multi-Ethnic Study of Atherosclerosis. *Am J Obstet Gynecol*. 2019;221:631.e1–631.e16. DOI: 10.1016/j.ajog.2019.07.001.

30. World Health Organization. Obesity among adults. 2016. Available at: https://www.who.int/gho/ncd/risk_factors/overweight_obesity/obesity_adults/en/. Accessed March 1, 2020.

31. Springer AE, Lewis K, Kelder SH, Fernandez ME, Barroso CS, Hoelscher DM. Physical activity participation by parental language use in 4th, 8th, and 11th grade students in Texas, USA. *J Immigr Minor Health*. 2010;12:769–780. DOI: 10.1007/s10903-009-9249-4.

32. Crespo CJ, Smit E, Carter-Pokras O, Andersen R. Acculturation and leisure-time physical inactivity in Mexican American adults: results from NHANES III, 1988–1994. *Am J Public Health*. 2001;91:1254–1257. DOI: 10.2105/AJPH.91.8.1254.

33. Neuhouser ML, Thompson B, Coronado GD, Solomon CC. Higher fat intake and lower fruit and vegetables intakes are associated with greater acculturation among Mexicans living in Washington State. *J Am Diet Assoc*. 2004;104:51–57. DOI: 10.1016/j.jada.2003.10.015.

34. United States Census Bureau. Demographic turning points for the United States: population projections for 2020 to 2060. 2020. Available at: https://www.census.gov/library/publications/2020/demo/p25-1144.html. Accessed March 1, 2020.

35. Israel BA, Schulz AJ, Parker EA, Becker AB. Review of community-based research: assessing partnership approaches to improve public health. *Annu Rev Public Health*. 1998;19:173–202. DOI: 10.1146/annurev.publhealth.19.1.173.

36. Ziebarth D, Healy-Haney N, Gnadt B, Cronin L, Jones B, Jensen E, Viscuso M. A community-based family intervention program to improve obesity in Hispanic families. *WMJ*. 2012;111:261–266.

37. Cullen KW, Lara Smalling A, Thompson D, Watson KB, Reed D, Konzelmann K. Creating healthful home food environments: results of a study with participants in the expanded food and nutrition education program. *J Nutr Educ Behav*. 2009;41:380–388. DOI: 10.1016/j.jneb.2008.12.007.

38. Virani SS, Alonso A, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, Chamberlain AM, Chang AR, Cheng S, Delling FN, et al. Heart disease and stroke statistics-2020 update: a report from the American Heart Association. *Circulation*. 2020;141:e139–e596. DOI: 10.1161/CIR.0000000000000757.

39. Martin AB, Hartman M, Washington B, Catlin A; National Health Expenditure Accounts Team. National health spending: faster growth in 2015 as coverage expands and utilization increases. *Health Aff*. 2017;36:166–176. DOI: 10.1377/hlthaff.2016.1330.

40. Lutsey PL, Diez Roux AV, Jacobs DR Jr, Burke GL, Harman J, Shea S, Folsom AR. Associations of acculturation and socioeconomic status with subclinical cardiovascular disease in the Multi-Ethnic Study of Atherosclerosis. *Am J Public Health*. 2008;98:1963–1970. DOI: 10.2105/AJPH.2007.123844.

41. Eamranond PP, Legedza AT, Diez-Roux AV, Kandula NR, Palmas W, Siscovick DS, Mukamal KJ. Association between language and risk factor levels among Hispanic adults with hypertension, hypercholesterolemia, or diabetes. *Am Heart J*. 2009;157:53–59. DOI: 10.1016/j.ahj.2008.08.015.

42. Marin G, Sabogal F, Marin BV, Otero-Sabogal R, Perez-Stable EJ. Development of a short acculturation scale for hispanics. *Hisp J Behav Sci*. 1987;9:183–205. DOI: 10.1177/07399863870092005.

43. Manichaikul A, Palmas W, Rodriguez CJ, Peralta CA, Divers J, Guo X, Chen W-M, Wong Q, Williams K, Kerr KF, et al. Population structure of Hispanics in the United States: the Multi-Ethnic Study of Atherosclerosis. *PLoS Genet*. 2012;8:e1002640. DOI: 10.1371/journal.pgen.1002640.

SUPPLEMENTAL MATERIAL

Table S1: Distribution of the cardiovascular health metrics.

Table S2: Multivariable association between acculturation and cardiovascular health score stratified by age.

Table S3: Distribution of the cardiovascular health metrics by generations in the United States.

Table S4: Multivariable association between generations in the United States and cardiovascular health score.

Table S5: Multivariable association between generations in the United States and the cardiovascular health metrics.

Figure S1: Percentage distribution of the cardiovascular health score by generations in the United States.

Table S1 – Distribution of the CVH metrics

CVH metrics	Point	Definition	% MESA Participants N = 6506
Smoking	0	Current smoker	839 (13%)
	1	Former smoker, quit ≤12 months ago	80 (1%)
	2	Never smoker or quit >12 months ago	5,587 (86%)
Body Mass Index	0	≥30 kg/m^2	2,073 (32%)
	1	25.0–29.99 kg/m^2	2,558 (39%)
	2	<25.0 kg/m^2	1,875 (29%)
Physical Activity	0	No exercise	1,486 (23%)
	1	1–149 min of moderate exercise or 1–74 min of vigorous exercise/week	1,128 (17%)
	2	150+ min of moderate exercise or 75+ min of vigorous exercise/week	3,892 (60%)
Diet	0	0–1 components of healthy diet	2,943 (45%)
	1	2–3 components of healthy diet	3,493 (54%)
	2	4–5 components of healthy diet	70 (1%)
Total Cholesterol	0	≥240 mg/dL	872 (13%)
	1	200–239 mg/dL or treated to <200mg/dL	2,544 (39%)
	2	<200 mg/dL, unmedicated	3,090 (47%)
Blood Pressure	0	SBP ≥140 mmHg or DBP ≥90 mmHg	2,439 (37%)
	1	SBP 120–139 mmHg or DBP 80–89 mmHg or treated to <120/80 mm Hg	1,819 (28%)
	2	<120/80 mm Hg, unmedicated	2,248 (35%)
Blood Glucose	0	≥126 mg/dL fasting	700 (11%)
	1	100–125 mg/dL fasting or treated to <100 mg/dL	987 (15%)
	2	<100 mg/dL fasting, unmedicated	4,819 (74%)

Adapted from Lloyd Jones et al [11] and Unger et al [22].
Abbreviations: CVH, cardiovascular health; DBP, diastolic blood pressure, MESA, Multi-Ethnic Study of Atherosclerosis and SBP, systolic blood pressure. Poor=0 points; Intermediate=1 point; ideal =2 points. *When combining vigorous and moderate exercise, vigorous exercise was weighted double**.**

Table S2. Multivariable association between acculturation and cardiovascular health score stratified by age

	<65 years		>=65	
	Average vs Inadequate	Optimal vs Inadequate	Average vs Inadequate	Optimal vs Inadequate
Birthplace	OR (95% CI)		OR (95% CI)	
Foreign-born	reference	reference	reference	reference
US-born	**0.72 (0.57-0.92)**	**0.58 (0.44-0.78)**	0.91 (0.67-1.23)	0.75 (0.51-1.09)
Years lived in the US*	OR (95% CI)		OR (95% CI)	
Tertile 1	reference	reference	reference	reference
Tertile 2	0.74 (0.52-1.06)	0.79 (0.53-1.17)	**0.58 (0.35-0.96)**	1.02 (0.57-1.81)
Tertile 3	**0.47 (0.31-0.70)**	**0.39 (0.24-0.63)**	0.73 (0.43-1.22)	0.86 (0.45-1.64)

Abbreviations: CI, confidence interval; OR, odds ratio; US, United States.
Model adjusted for sex, race/ethnicity, education, income and health insurance.
Cardiovascular health score ranges from 0-14; inadequate score, 0-8; average, 9-10; optimal, 11-14.

Table S3. Distribution of CVH metrics by generations in the US, N = 6,281				
	0	**1st**	**2rd**	**3rd**
	n= 2,093	n= 798	n= 743	n= 2,647
Smoking				
Poor	205 (10%)	77 (10%)	83 (11%)	442 (17%)
Intermediate	22 (1%)	9 (1%)	11 (1%)	35 (1%)
Ideal	1,866 (89%)	712 (89%)	649 (87%)	2,170 (82%)
Body mass index				
Poor	485 (23%)	273 (34%)	242 (33%)	995 (38%)
Intermediate	831 (40%)	321 (40%)	291 (39%)	1,023 (39%)
Ideal	777 (37%)	204 (26%)	210 (28%)	629 (24%)
Physical activity				
Poor	615 (29%)	152 (19%)	118 (16%)	557 (21%)
Intermediate	368 (18%)	120 (15%)	137 (18%)	462 (17%)
Ideal	1,110 (53%)	526 (66%)	488 (66%)	1,628 (62%)
Diet				
Poor	789 (38%)	378 (47%)	359 (48%)	1,301 (49%)
Intermediate	1,278 (61%)	411 (52%)	376 (51%)	1,322 (50%)
Ideal	26 (1%)	9 (1%)	8 (1%)	24 (1%)
Total Cholesterol				
Poor	301 (14%)	107 (13%)	111 (15%)	334 (13%)
Intermediate	751 (36%)	330 (41%)	331 (45%)	1,034 (39%)
Ideal	1,041 (50%)	361 (45%)	301 (41%)	1,279 (48%)
Blood pressure				
Poor	722 (35%)	296 (37%)	192 (26%)	1,127 (43%)
Intermediate	580 (28%)	227 (28%)	217 (29%)	739 (28%)
Ideal	791 (38%)	275 (34%)	334 (45%)	781 (30%)
Blood glucose				
Poor	266 (13%)	72 (9%)	54 (7%)	277 (10%)
Intermediate	368 (18%)	124 (16%)	86 (12%)	380 (14%)
Ideal	1,459 (70%)	602 (75%)	603 (81%)	1,990 (75%)

Abbreviation: CVH, cardiovascular health; US, United States.
Percentages (%) are rounded up to whole numbers.

Table S4. Multivariable association between generations in the US and cardiovascular health score

Generations	Average vs Inadequate	Optimal vs Inadequate	Average vs Inadequate	Optimal vs Inadequate
	Model 1		Model 2	
	OR (95% CI)		OR (95% CI)	
0	reference	reference	reference	reference
1st	1.04 (0.86-1.25)	0.95 (0.76-1.17)	0.92 (0.74-1.15)	0.77 (0.59-1.01)
2nd	1.13 (0.93-1.38)	**1.27 (1.02-1.57)**	**0.77 (0.60-0.99)**	**0.63 (0.47-0.84)**
3rd	**0.76 (0.67-0.87)**	**0.62 (0.53-0.73)**	**0.70 (0.56-0.86)**	**0.51 (0.40-0.66)**

Abbreviations: CI, confidence interval; OR, odds ratio; US, United States.
Model 1: unadjusted.
Model 2: adjusted for age, sex, race/ethnicity, education, income and health insurance.
Cardiovascular health score ranges from 0-14; inadequate score, 0-8; average, 9-10; optimal, 11-14.
Interaction by age, sex and race/ethnicity were not statistically significant at P<0.05.

Table S5 - Multivariable association between generations in the US and the CVH metrics

Generations	Smoking Intermediate vs. poor OR (95% CI)	Smoking Ideal vs. Poor OR (95% CI)	Body Mass Index Intermediate vs. poor OR (95% CI)	Body Mass Index Ideal vs. Poor OR (95% CI)	Physical Activity Intermediate vs. poor OR (95% CI)	Physical Activity Ideal vs. Poor OR (95% CI)	Diet Intermediate vs. poor OR (95% CI)	Diet Ideal vs. Poor OR (95% CI)
0	reference	reference	reference	reference	reference	reference	reference	reference
1st	0.74 (0.29-1.89)	0.78 (0.57-1.08)	**0.64 (0.51-0.81)**	**0.54 (0.41-0.71)**	1.20 (0.88-1.65)	**1.30 (1.02-1.66)**	**0.62 (0.51-0.76)**	**0.40 (0.16-0.99)**
2nd	0.79 (0.30-2.06)	0.76 (0.54-1.07)	**0.66 (0.51-0.84)**	**0.54 (0.40-0.71)**	**1.44 (1.02-2.05)**	1.30 (0.98-1.71)	**0.58 (0.46-0.72)**	**0.33 (0.12- 0.87)**
3rd	0.63 (0.27-1.48)	**0.55 (0.41-0.73)**	**0.76 (0.61-0.95)**	**0.63 (0.49-0.81)**	1.20 (0.89-1.62)	1.13 (0.89-1.42)	**0.50 (0.41-0.61)**	**0.22 (0.10- 0.49)**

Generation	Total Cholesterol Intermediate vs. poor OR (95% CI)	Total Cholesterol Ideal vs. Poor OR (95% CI)	Blood Pressure Intermediate vs. poor OR (95% CI)	Blood Pressure Ideal vs. Poor OR (95% CI)	Blood Glucose Intermediate vs. poor OR (95% CI)	Blood Glucose Ideal vs. Poor OR (95% CI)
0	reference	reference	reference	reference	reference	reference
1st	1.19 (0.88-1.60)	1.14 (0.85-1.53)	0.86 (0.67-1.09)	0.97 (0.76-1.24)	0.93 (0.64-1.36)	0.94 (0.68-1.30)
2nd	1.12 (0.81-1.54)	0.86 (0.62-1.19)	0.93 (0.70-1.23)	0.96 (0.73-1.27)	**0.60 (0.38-0.95)**	**0.63 (0.43-0.93)**
3rd	1.14 (0.86-1.52)	1.10 (0.83-1.46)	**0.69 (0.54-0.87)**	**0.59 (0.47-0.75)**	**0.66 (0.45-0.97)**	**0.68 (0.49-0.94)**

Abbreviations: CI, confidence interval; CVH, cardiovascular health; OR, odds ratio; US, United States.
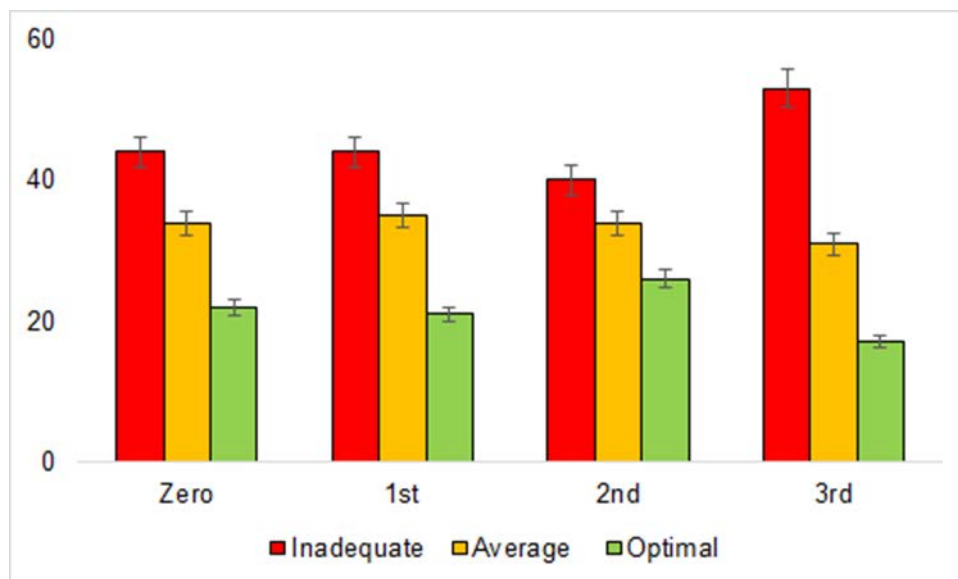Model adjusted for age, sex, race/ethnicity, education, income and health insurance.

Figure S1 Legend

Percentage distribution of the cardiovascular health (CVH) score by generations in the United States (US). Red: inadequate (0-8 points), Orange: average (9-10 points) and Green: optimal (11-14 points). Error bars on the bar graphs represent percentage error.