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Acculturation and Cardiometabolic Abnormalities Among Chinese and Korean Americans

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Abstract

Background Studies generally show that higher acculturation is associated with greater cardiovascular disease (CVD) risk among immigrants in the United States (US). However, few studies have compared how proxies of acculturation are differentially associated with metabolic abnormalities measured using objective biomarkers, self-reported diagnosis, and medication use, particularly among East Asian Americans.

Methods Survey data and biomarker measurements collected from random (non-fasting) blood samples of Chinese and Korean immigrants in the US ($n = 328$) were used to examine the associations between two proxies for acculturation (years living in the US and English speaking proficiency) with three cardiometabolic abnormalities (high triglyceride levels, diabetes, and hypercholesterolemia). Poisson regression models estimated prevalence ratios adjusted for demographic characteristics, socioeconomic factors, and body mass index. Gender, Asian subgroup, and household income were tested as potential effect modifiers.

Results Living longer in the US was associated with greater likelihood of having high triglycerides. In addition, living longer in the US was associated with greater likelihood of diabetes for people with lower household income and greater likelihood of hypercholesterolemia for people with higher household income. Higher level of English proficiency was less consistently associated with higher cardiometabolic risk, although there was a significant association with greater likelihood of hypercholesterolemia.

Conclusions Longer time lived in the US is associated with higher risk of cardiometabolic abnormalities among Chinese and Korean Americans. Future studies of acculturation and cardiometabolic risk should carefully consider potential mechanisms and what proxy measures of acculturation capture.

Trial Registration Number NCT03481296, date of registration: 3/29/2018.

Keywords Acculturation · Cardiometabolic disease · Asian Americans · Immigrants · Diabetes · Hypercholesterolemia

Introduction

Research on the health of immigrants in Western contexts has demonstrated that greater levels of acculturation are commonly associated with greater cardiovascular disease risk [1]. Acculturation is broadly defined here as a process of adaptation that immigrants undergo in order to adjust to the new sociocultural environment of their host society [2]. One recent review found that among Latinx and South Asians in the United States (US), longer length of residence in the US was associated with greater cardiovascular risk and mortality across several studies [3]. Research has begun to link acculturation with metabolic abnormalities known to increase risk for cardiovascular disease, such as higher body mass index [4, 5], abdominal obesity [6, 7], and type

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II diabetes [8, 9]. However, fewer studies have examined this association using biomarkers of metabolic abnormalities such as lipid, cholesterol, and glucose levels in the blood that provide more objective measurement of arteriosclerosis risk and type II diabetes.

Those that have examined the role of acculturation in relation to cardiometabolic disease markers are somewhat mixed in their results. While most literature points to greater acculturation being associated with self-reported diabetes [9–15], one study found that acculturation was not associated with diabetes defined using blood glucose levels among Chinese and Mexican-origin participants [16]. Another study among South Asian immigrants in the US using blood glucose levels found the opposite association—higher acculturation was associated with lower blood glucose levels among women [17]. The literature is less clear with regard to lipid and cholesterol levels. Although a few studies have found an association between acculturation and hypercholesterolemia among immigrants [18, 19], other studies have found no association between acculturation and high cholesterol [20, 21]. One study found an association between greater acculturation and hyperlipidemia among immigrant women only, not immigrant men [10]. Overall, this literature suggests that the associations between acculturation and metabolic syndrome are complicated and likely vary depending on the indicator of cardiometabolic risk, immigrant country of ancestry, and the measure of acculturation.

It is important to note that when researchers measure acculturation in medical research, they do so using proxy measurements. Acculturation is a complex concept regarding how immigrants change and adapt to the norms, values, and practices of the society they live in. While some studies use rough proxies such as nativity or generational status [1, 18], the majority of studies on cardiovascular disease use length of residence in the host country [9, 10, 15, 22]. Still, others use language as a proxy for acculturation. In the US context, this is often measured using either language spoken at home or English language proficiency [12, 13, 16]. Prior work has noted that these proxies capture different aspects of the immigrant experience. For example, while length of residence might be an indication of a longer time of exposure to a particular social or physical (i.e. built, chemical toxins) environment, English proficiency may better capture ability to navigate society and the complex US health care system [23]. English proficiency may also be highly associated with education and other indicators of socioeconomic status. Therefore, it is potentially revealing to examine how various proxy measures of acculturation could be differentially related to metabolic risk.

While much of the research on acculturation and cardiometabolic risk in the US has focused on immigrants from Latin America [12–14], or on immigrant populations generally [10, 11], few studies have had large enough sample sizes to examine this association in East Asian Americans. Those that have were older studies conducted among Japanese Americans (Huang et al. 1996; Hosler & Melnik 2003) or more recently among South Asian immigrants [17, 22]. One study examining Chinese Americans found no association between acculturation and cardiometabolic risk, including diabetes [16], while another population-based study found an opposite association with higher acculturation being associated with lower diabetes risk among Asian Americans as a whole [18]. No study to date has found a significant association between acculturation and high lipids or cholesterol among East Asian Americans [18].

The purpose of this study is to examine the associations between acculturation proxies and cardiometabolic risk using measures taken from blood samples as well as self-reported diagnoses. Importantly, this is one of the few studies to calculate these associations among a sample of East Asian Americans, namely Chinese and Korean American immigrants. We examined two proxies of acculturation—years in the US and English speaking proficiency—in relation to three markers of cardiometabolic risk—high triglyceride levels, diabetes, and hypercholesterolemia. Our hypotheses were as follows: (1) higher levels of acculturation would be associated with higher cardiometabolic risk, (2) the associations between acculturation and cardiometabolic risk factors would differ in strength depending on the proxy measure of acculturation, and (3) the associations between acculturation and cardiometabolic risk would be moderated by gender, Asian subgroup, or income. Previous studies have suggested that the association between acculturation on cardiometabolic risk might vary by these sociodemographic factors [10, 16, 24, 25].

Methods

Sample

We used data from a randomized controlled trial to increase colorectal cancer screening among 400 Chinese and Korean Americans (200 Chinese and 200 Korean Americans). Study participants were between the ages of 50 and 75, living in the Baltimore-Washington DC Metropolitan Area, and they were recruited from primary care physicians' clinics in Maryland and Northern Virginia. The baseline survey data were collected from August 2018 to June 2020. After signing informed consent forms, 400 participants completed the survey either in-person or by phone in their preferred language (Mandarin, Korean, or English). Eighty-nine percent of the participants (155 Chinese and 200 Korean Americans) completed a self-administered questionnaire in-person, while 11% of the participants (45 Chinese Americans) completed a research assistant-led phone survey because of the COVID-19 outbreak in March 2020. This study was approved by the Institutional Review Boards of the University of Maryland, College Park and the University of California, Irvine.

We collected self-reported information on diagnosis of hypercholesterolemia and diabetes by a physician and medication use for all participants. Trained research assistants collected anthropometric measurements (e.g., height and weight) and blood samples for the participants who completed in-person baseline survey ($n = 355$). Blood samples could not be provided by those who completed a phone survey ($n = 45$) due to the COVID-19 pandemic. A blood measuring device (CardioChek Analyzer, Polymer Technology Systems, Inc.) was used to estimate total triglycerides, cholesterol, and glucose. The highest possible triglyceride level reading was 500 mg/dL, and the lowest possible cholesterol level reading was 100 mg/dL. We had nine participants who had triglycerides values of 500 mg/dL and five participants who had total cholesterol values of 100 mg/dL. Since participants were being recruited at physicians' clinics, participants were not required to fast prior to providing blood samples which were taken anytime between mid-morning to afternoon, so biomarker measurements were considered random (non-fasting). Although fasting triglyceride and glucose measurements are preferable, it was not possible to require participants to fast for 12 hours or overnight given the time of meeting. Therefore, we determined appropriate cutoff points based on medical guidelines for elevated triglycerides and glucose levels measured from random blood tests [26–28]. For the 355 people who completed an in-person survey, 25 participants declined to participate in blood sample collection, and two participants had missing values for triglycerides due to machine errors. Therefore, our analytic sample was $n = 328$.

Dependent Variables

Our dependent variables included high triglycerides, diabetes, and hypercholesterolemia. Having high triglycerides was defined as having a triglyceride level ≥ 200 mg/dL, and normal triglycerides were defined as having a triglyceride level < 200 mg/dL based on the random non-fasting blood measurement only. This level of 200 mg/dL or higher is based on medical recommendations for treatment based on chronic disease risk at this elevated level of triglycerides [26, 29]. Diabetes and hypercholesterolemia were based on a combination of objective biomarker measurements taken from the random non-fasting blood samples and two self-reported variables. Diabetes was defined as having one or more of the following: random non-fasting blood glucose measurement ≥ 200 mg/dL [27], self-report of currently taking anti-diabetes medication, or self-report of having been diagnosed with diabetes by a doctor or other healthcare professional in the past year or ever. Hypercholesterolemia was defined as having one or more of the following: random non-fasting total cholesterol measurement ≥ 240 mg/dL [28], self-report of currently taking anti-hypercholesterolemia medication, or self-report of having been diagnosed with high cholesterol by a doctor or other healthcare professional in the past year or ever. Both hypercholesterolemia and diabetes were used as binary variables in the analyses to distinguish between those who likely have these chronic conditions versus those who do not.

Acculturation

Acculturation was assessed using two variables: years living in the US and English proficiency. Years living in the US were calculated using the year difference between the date of baseline survey and the date of arriving in the US. In analyses, we used years living in the US as a dichotomous variable using 23 years (the median years lived in the US in our sample), for ease of interpretation. This binary variable was coded as either having lived in the US ≥ 23 years or having lived in the US < 23 years. In sensitivity analyses, we repeated the same analysis using years in the US as a continuous variable, with similar results (results for continuous years in the US not shown, but available upon request). English proficiency was evaluated using the question, "How well do you speak English?" Responses were recoded into three categories: "fluently like a native speaker/well," "so-so," or "poorly/not at all."

Covariates

The following sociodemographic characteristics were included in the analysis: age, gender, Asian subgroup, marital status, education, household income, employment status, and health insurance status. Age was used as a continuous variable in years, gender was classified as male or female, and Asian subgroup was categorized as Chinese or Korean. Marital status was used as a binary variable: married/cohabiting or not currently married. Education was recoded into five categories: less than high school, high school graduate or GED, business/vocational school/some college, college graduate, or attended graduate/professional school. We treated household income as six categories in regression analysis: < $20,000, $20,000–$39,999, $40,000–$59,999, $60,000–$79,999, $80,000–$99,999, or ≥ $100,000. When examined as an effect modifier, we treated household income as two categories, with a cut-off point of about 150% of the Federal Poverty Guideline for a family of four persons in 2020: < $40,000 or ≥ $40,000 [30]. Employment status was categorized as full time, part time, or not employed. Health insurance status was recoded as private health insurance, Medicare/Medicaid, or no health insurance. BMI was also included as a covariate, calculated by dividing weight in pounds by height in inches squared and multiplying by a conversion factor of 703.

Statistical Analysis

First, descriptive analysis was conducted for the sample overall and stratified by years living in the US. Means and standard errors were reported for continuous variables and frequencies and percentages were reported for categorical variables. Two sample *t*-tests for continuous variables and chi-square tests for categorical variables were conducted to compare the differences by years living in the US. Second, Poisson regression models with robust error variance were used to estimate associations between each acculturation variable separately (years living in the US or English proficiency) with outcomes (high triglycerides, diabetes, and hypercholesterolemia). Poisson regression models were used as the preferred method to estimate prevalence ratios (PRs) in lieu of logistic models that may overestimate the associations using odds ratios, since all three outcomes were prevalent in the sample at greater than 10% [31]. Epidemiologists suggest using Poisson regression to estimate PRs for cross-sectional analyses with outcomes that are prevalent at greater than 10% in the sample [32, 33]. Poisson regression estimated PRs and 95% confidence intervals (CIs) using two models for each outcome. Model 1 included acculturation (years living in the US or English proficiency), adjusting for age, gender, Asian subgroup, and marital status. Model 2 added education, household income, employment status, health insurance status, and BMI to Model 1. Then, we tested gender, Asian subgroup, and household income as potential effect modifiers of the associations between acculturation and the outcomes adjusting for all covariates. When the effect modifiers were significant at $p < 0.05$, we conducted stratified analyses (non-significant findings not shown, but available upon request). All statistical analyses were computed using Stata version 14.2.

Results

Table 1 presents the characteristics of the study participants. Of the 328 participants, 158 (48.2%) lived less than 23 years in the US, while 170 (51.8%) lived equal to or longer than 23 years in the US. The ≥ 23 years in the US group had a significantly higher proportion of Korean Americans (67.1%) and Medicare/Medicaid recipients (25.9%) compared to the < 23 years in the US group (Korean: 48.7%, Medicare/Medicaid: 13.9%). Those living ≥ 23 years in the US were more likely to have high income than those who lived less than 23 years in the US. Those who lived in the US for longer had a higher proportion of people with high triglycerides (44.7%) based on random blood measurement compared to those who lived in the US for a shorter amount of time (34.2%). In addition, English proficiency differed among two groups: 27.7% of participants who lived in the US longer spoke English fluently like a native speaker/well, while only 13.3% participants who lived in the US for a shorter time did.

Table 2 shows the results of Poisson regression models to estimate the associations between years living in the US, high triglycerides, diabetes, and hypercholesterolemia. Individuals living in the US for shorter amount of time were less likely to have high triglycerides level: the < 23 years in the US group had 0.76 (95% CI: 0.57–1.00) times the prevalence of having high triglycerides compared to the ≥ 23 years in the US group in Model 1, accounting for age, gender, Asian subgroup, and marital status. The direction and significance of association were maintained in Model 2 (PR = 0.71; 95% CI: 0.52–0.95) with further adjustment for education, household income, employment status, health insurance status, and BMI. Years lived in the US were not highly associated with diabetes or with hypercholesterolemia. Among the covariates, BMI was positively associated with having high triglycerides (PR = 1.04, 95% CI: 1.00–1.08) and with hypercholesterolemia (PR = 1.04, 95% CI: 1.01–1.06). Older age was positively associated with prevalence of diabetes (PR = 1.05, 95% CI: 1.02–1.10) and hypercholesterolemia (PR = 1.03, 95% CI: 1.01–1.05).

Table 3 displays the results of Poisson regression models to estimate the associations between English proficiency, high triglycerides, diabetes, and hypercholesterolemia. English proficiency was not strongly associated with high triglycerides or diabetes. Individuals who reported speaking English so-so relative to those speaking fluently like a native speaker/well were less likely to have hypercholesterolemia. When only age, gender, Asian subgroup, and marital status were adjusted for, speaking English so-so compared to fluently/well was associated with 0.69 times the prevalence of having hypercholesterolemia in Model 1 (95% CI: 0.51–0.94), and the association was maintained in Model 2 (PR: 0.70, 95% CI: 0.50–0.97). Speaking English poorly/not at all was also associated with 0.86 times lower prevalence of having hypercholesterolemia compared to those speaking English fluently/well, but this association was not strong (95% CI: 0.59–1.26).

We tested gender, Asian subgroup, and household income as potential effect modifiers of the associations between two measures of acculturation and all dependent variables. Household income was the only significant effect modifier of the association between years living in the US and diabetes and of the association between years living in the US and hypercholesterolemia when $p < 0.05$. The stratified results are shown in Table 4. Among the participants with household income < \$40,000, people living in the US < 23 years

Table 1 Characteristics of the study participants ($n = 328$)

		Years living in the US		*p*-value
	Total *n* = 328 (100%)	< 23 years *n* = 158 (48.2%)	≥ 23 years *n* = 170 (51.8%)	
Age, mean (SE)	58.67 (0.35)	58.20 (0.48)	59.11 (0.50)	0.1913
Gender, *n* (%)				
Female	173 (52.7)	86 (54.4)	87 (51.2)	0.5553
Male	155 (47.3)	72 (45.6)	83 (48.8)	
Asian subgroup, *n* (%)				
Chinese	137 (41.8)	81 (51.3)	56 (32.9)	0.0008
Korean	191 (58.2)	77 (48.7)	114 (67.1)	
Marital status, *n* (%)				
Not currently married	48 (14.6)	24 (15.2)	24 (14.1)	0.7837
Married/cohabiting	280 (85.4)	134 (84.8)	146 (85.9)	
Education, *n* (%)				
Less than high school	36 (11.0)	19 (12.0)	17 (10.0)	0.4580
High school graduate or GED	78 (23.8)	38 (24.1)	40 (23.5)	
Business/vocational school/some college	55 (16.8)	23 (14.6)	32 (18.8)	
College graduate	88 (26.8)	48 (30.4)	40 (23.5)	
Attended graduate/professional school	71 (21.7)	30 (19.0)	41 (24.1)	
Household income, *n* (%)				
< $20,000	54 (16.5)	32 (20.3)	22 (12.9)	0.0537
$20,000–39,999	56 (17.1)	33 (20.9)	23 (13.5)	
$40,000–59,999	72 (22.0)	32 (20.3)	40 (23.5)	
$60,000–79,999	43 (13.1)	20 (12.7)	23 (13.5)	
$80,000–99,999	20 (6.1)	11 (7.0)	9 (5.3)	
≥ $100,000	83 (25.3)	30 (19.0)	53 (31.2)	
Employment status, *n* (%)				
Working full time	190 (57.9)	84 (53.2)	106 (62.4)	0.2420
Working part time	71 (21.7)	38 (24.1)	33 (19.4)	
Not currently working	67 (20.4)	36 (22.8)	31 (18.2)	
Health insurance status, *n* (%)				
Private health insurance	191 (58.2)	96 (60.8)	95 (55.9)	0.0179
Medicare/Medicaid	66 (20.1)	22 (13.9)	44 (25.9)	
No health insurance	71 (21.7)	40 (25.3)	31 (18.2)	
Triglycerides, *n* (%)				
Normal	198 (60.4)	104 (65.8)	94 (55.3)	0.0514
High	130 (39.6)	54 (34.2)	76 (44.7)	
Diabetes, *n* (%)				
No	250 (76.2)	125 (79.1)	125 (73.5)	0.2352
Yes	78 (23.8)	33 (20.9)	45 (26.5)	
Hypercholesterolemia, *n* (%)				
No	165 (50.3)	84 (53.2)	81 (47.7)	0.3180
Yes	163 (49.7)	74 (46.8)	89 (52.4)	
BMI, mean (SE)	24.65 (0.20)	24.46 (0.31)	24.82 (0.25)	0.3604
English proficiency, *n* (%)				
Fluently like a native speaker/well	68 (20.7)	21 (13.3)	47 (27.7)	< .0001
So-so	127 (38.7)	44 (27.9)	83 (48.8)	
Poorly/not at all	133 (40.6)	93 (58.9)	40 (23.5)	

Table 2 Poisson regression analyses: associations between years living in the US, high triglycerides, diabetes, and hypercholesterolemia ($n = 328$)

	High triglycerides		Diabetes		Hypercholesterolemia	
	PR (95% CI)		PR (95% CI)		PR (95% CI)	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Years living in the US						
≥ 23 years	1.00	1.00	1.00	1.00	1.00	1.00
< 23 years	0.76 (0.57–1.00)*	0.71 (0.52–0.95)*	0.89 (0.60–1.33)	0.88 (0.58–1.35)	0.93 (0.75–1.16)	0.94 (0.75–1.18)
Age	1.01 (0.99–1.03)	1.00 (0.98–1.03)	1.04 (1.01–1.08)**	1.06 (1.02–1.10)**	1.03 (1.01–1.05)**	1.03 (1.01–1.05)**
Gender						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	0.92 (0.70–1.21)	0.83 (0.63–1.11)	0.89 (0.61–1.31)	0.88 (0.57–1.36)	1.14 (0.91–1.42)	1.17 (0.91–1.50)
Asian subgroup						
Korean	1.00	1.00	1.00	1.00	1.00	1.00
Chinese	1.12 (0.84–1.49)	1.08 (0.80–1.45)	0.70 (0.44–1.10)	0.75 (0.46–1.21)	0.91 (0.72–1.16)	0.90 (0.70–1.15)
Marital status						
Married/cohabit	1.00	1.00	1.00	1.00	1.00	1.00
Not currently married	1.14 (0.80–1.62)	1.32 (0.91–1.90)	0.63 (0.32–1.24)	0.70 (0.35–1.41)	0.98 (0.73–1.31)	1.05 (0.77–1.45)
Education						
Less than high school		0.93 (0.52–1.66)		1.31 (0.57–3.00)		1.06 (0.67–1.65)
High school graduate or GED		1.13 (0.71–1.81)		1.29 (0.62–2.67)		1.11 (0.76–1.60)
Business/vocational school/some college		1.13 (0.72–1.80)		1.49 (0.71–3.11)		0.94 (0.62–1.42)
College graduate		0.88 (0.54–1.44)		1.39 (0.69–2.77)		1.07 (0.75–1.52)
Attended graduate/professional school		1.00		1.00		1.00
Income						
< $20,000		1.38 (0.81–2.35)		0.90 (0.47–1.75)		0.88 (0.57–1.34)
$20,000–39,999		1.28 (0.78–2.10)		0.72 (0.35–1.49)		0.98 (0.67–1.44)
$40,000–59,999		1.22 (0.77–1.92)		0.93 (0.51–1.73)		0.84 (0.59–1.20)
$60,000–79,999		1.03 (0.59–1.82)		0.68 (0.31–1.51)		1.02 (0.68–1.52)
$80,000–99,999		0.93 (0.46–1.91)		1.19 (0.53–2.70)		0.58 (0.29–1.14)
≥ $100,000		1.00		1.00		1.00
Employment status						
Working full time		1.00		1.00		1.00
Working part time		1.08 (0.76–1.54)		1.44 (0.90–2.30)		0.98 (0.73–1.32)
Not currently working		1.45 (0.99–2.13)†		1.00 (0.55–1.81)		1.01 (0.75–1.37)
Health insurance						
Private health insurance		1.00		1.00		1.00
Medicare/Medicaid		0.69 (0.45–1.05)†		0.72 (0.41–1.28)		0.91 (0.65–1.28)
No health insurance		0.80 (0.55–1.18)		0.87 (0.52–1.44)		0.94 (0.69–1.27)
BMI		1.04 (1.00–1.08)*		1.04 (0.99–1.09)		1.04 (1.01–1.06)**

$^{\dagger}p < 0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$. Model 1: years living in the US + age, gender, Asian subgroup, marital status. Model 2: Model 1 + education, income, employment status, health insurance, BMI. High triglycerides are based on random blood triglycerides ≥ 200 mg/dL. Diabetes is based on random blood glucose ≥ 200 mg/dL, self-reported diagnosis from a doctor, or self-reported diabetes medication usage. Hypercholesterolemia is based random blood cholesterol ≥ 240 mg/dL, self-reported diagnosis from a doctor, or self-reported hypercholesterolemia medication usage

PR prevalence ratio, *CI* confidence interval

Table 3 Poisson regression analyses: associations between English proficiency, high triglycerides, diabetes, and hypercholesterolemia ($n = 328$)

	High triglycerides		Diabetes		Hypercholesterolemia	
	PR (95% CI)		PR (95% CI)		PR (95% CI)	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 3
English proficiency						
Fluent like a native speaker/well	1.00	1.00	1.00	1.00	1.00	1.00
So-so	0.97 (0.66–1.44)	0.93 (0.61–1.44)	0.98 (0.56–1.71)	0.95 (0.52–1.71)	0.69 (0.51–0.94)*	0.70 (0.50–0.97)*
Poorly/not at all	1.10 (0.76–1.61)	0.98 (0.59–1.64)	0.97 (0.56–1.70)	1.00 (0.50–1.99)	0.85 (0.64–1.13)	0.86 (0.59–1.26)
Age	1.01 (0.98–1.03)	1.00 (0.98–1.03)	1.04 (1.01–1.08)**	1.06 (1.02–1.10)**	1.03 (1.01–1.05)*	1.03 (1.01–1.06)**
Gender						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	0.91 (0.69–1.20)	0.85 (0.63–1.14)	0.89 (0.61–1.32)	0.89 (0.58–1.37)	1.17 (0.94–1.47)	1.20 (0.94–1.53)
Asian subgroup						
Korean	1.00	1.00	1.00	1.00	1.00	1.00
Chinese	1.05 (0.79–1.40)	1.01 (0.74–1.37)	0.68 (0.43–1.07)†	0.73 (0.44–1.19)	0.86 (0.68–1.09)	0.87 (0.67–1.12)
Marital status						
Married/cohabit	1.00	1.00	1.00	1.00	1.00	1.00
Not currently married	1.12 (0.79–1.60)	1.32 (0.91–1.91)	0.63 (0.32–1.23)	0.70 (0.35–1.39)	0.95 (0.71–1.28)	1.03 (0.75–1.41)
Education						
Less than high school		0.92 (0.48–1.77)		1.29 (0.50–3.33)		1.04 (0.62–1.75)
High school graduate or GED		1.11 (0.65–1.90)		1.28 (0.58–2.81)		1.12 (0.73–1.73)
Business/vocational school/some college		1.16 (0.71–1.90)		1.52 (0.73–3.18)		1.00 (0.65–1.55)
College graduate		0.86 (0.52–1.42)		1.38 (0.68–2.83)		1.11 (0.77–1.60)
Attended graduate/professional school		1.00		1.00		1.00
Income						
< $20,000		1.21 (0.70–2.10)		0.86 (0.45–1.67)		0.89 (0.57–1.39)
$20,000–39,999		1.17 (0.70–1.94)		0.70 (0.34–1.45)		1.04 (0.70–1.54)
$40,000–59,999		1.17 (0.73–1.85)		0.92 (0.50–1.71)		0.89 (0.61–1.30)
$60,000–79,999		1.00 (0.56–1.77)		0.67 (0.30–1.49)		1.09 (0.73–1.64)
$80,000–99,999		0.88 (0.43–1.80)		1.16 (0.52–2.60)		0.61 (0.31–1.19)
≥ $100,000		1.00		1.00		1.00
Employment status						
Working full time		1.00		1.00		1.00
Working part time		1.06 (0.74–1.53)		1.43 (0.90–2.29)		0.99 (0.73–1.33)
Not currently working		1.37 (0.93–2.04)		0.97 (0.53–1.79)		1.01 (0.74–1.37)
Health insurance						
Private health insurance		1.00		1.00		1.00
Medicare/Medicaid		0.74 (0.49–1.12)		0.74 (0.42–1.32)		0.88 (0.64–1.23)
No health insurance		0.79 (0.54–1.16)		0.87 (0.52–1.45)		0.91 (0.67–1.24)
BMI		1.04 (1.00–1.08)*		1.04 (0.99–1.09)		1.03 (1.01–1.06)*

$^{\dagger}p < 0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$. Model 1: English proficiency + age, gender, Asian subgroup, marital status. Model 2: Model 1 + education, income, employment status, health insurance, BMI. High triglycerides are based on random blood triglycerides ≥ 200 mg/dL. Diabetes is based on random blood glucose ≥ 200 mg/dL, self-reported diagnosis from a doctor, or self-reported diabetes medication usage. Hypercholesterolemia is based random blood cholesterol ≥ 240 mg/dL, self-reported diagnosis from a doctor, or self-reported hypercholesterolemia medication usage

PR prevalence ratio, *CI* confidence interval

were 0.41 times (95% CI: 0.19–0.87) less likely to have diabetes compared to those living in the US ≥ 23 years. On the contrary, there was not a strong association between years lived in the US and diabetes among participants with household income ≥ $40,000. Among the participants with household income < $40,000, years in the US were not strongly associated with hypercholesterolemia. However, for participants with income ≥ $40,000, those living in the

Table 4 Stratified analysis: associations of years living in the US with diabetes and hypercholesterolemia stratified by household income ($n = 328$)

	Household income	
	< \$40,000, $n = 110$	≥ \$40,000, $n = 218$
	PR (95% CI)	PR (95% CI)
Diabetes		
Years living in the US		
≥ 23 years	1.00	1.00
< 23 years	0.41 (0.19–0.87)*	1.16 (0.71–1.92)
Hypercholesterolemia		
Years living in the US		
≥ 23 years	1.00	1.00
< 23 years	1.37 (0.92–2.04)	0.71 (0.52–0.96)*

*$p < 0.05$. Covariates were age, gender, Asian subgroup, marital status, education, household income, employment status, health insurance status, and BMI. Diabetes is based on random blood glucose ≥ 200 mg/dL, self-reported diagnosis from a doctor, or self-reported diabetes medication usage. Hypercholesterolemia is based random blood cholesterol ≥ 240 mg/dL, self-reported diagnosis from a doctor, or self-reported hypercholesterolemia medication usage

PR prevalence ratio, *CI* confidence interval

US < 23 years were less likely to have hypercholesterolemia compared to those living in the US ≥ 23 years (PR: 0.71, 95% CI: 0.52–0.96).

Discussion

Asian Americans are currently the fastest growing population in the US and over half (57%) are foreign-born [34]. Cardiovascular disease is the second leading cause of death among Asian Americans, behind cancer [35], and they experience higher proportionate mortality from stroke compared to white Americans [36]. Further, Asian Americans are quite diverse, and very little data exists for cardiometabolic disease risk factors for East Asian American subgroups. Therefore, this paper seeks to clarify the important association between acculturation and cardiometabolic disease risk, specifically for Chinese and Korean American immigrants. Chinese and Korean Americans are two of the largest Asian American groups of the US, making up 24% and 9% of the total population of Asian Americans, respectively. To our knowledge, this is the first study to examine the association between acculturation and metabolic abnormalities for Korean Americans in particular.

In this study, we sought to examine the association between acculturation and cardiometabolic abnormalities for Chinese and Korean Americans. Specifically, we examined how two different measures of acculturation—years in the US and English proficiency—were associated with three cardiometabolic abnormalities—high triglycerides, diabetes, and hypercholesterolemia. We hypothesized that greater acculturation would be associated with higher prevalence of acardiometabolic abnormalities, and that this association would differ depending on the measure of acculturation. We found that in general, higher levels of acculturation were associated with more cardiometabolic abnormalities, confirming our first hypothesis. We also found that although these associations varied depending on the measure of acculturation and the outcome, confirming our second hypothesis.

Years in the US and English proficiency had different associations with metabolic abnormalities. Longer years lived in the US was associated with having high triglycerides after accounting for covariates including age, gender, Asian subgroup, marital status, socioeconomic status, health insurance status, and BMI. Those who lived in the US for less than 23 years had 0.71 times lower prevalence of high triglycerides than those who lived in the US for 23 or more years, accounting for all else. These findings indicate that for Chinese and Korean American immigrants, living longer in the US is a risk factor for uncontrolled levels of high triglycerides, even after accounting for age and other demographic and socioeconomic factors. Very few prior studies have examined the association between length of time in the US and high triglycerides using objective measurements taken from blood samples. Only one previous study among Asian Americans found that South Asians with higher acculturation had lower triglyceride levels [17]. Our study showed the opposite association, and it is the first to demonstrate a positive association between longer time lived in the US and higher triglycerides among Chinese and Korean immigrants. Triglycerides are an important biomarker of dyslipidemia and cardiovascular disease risk [37].

The associations between English proficiency and metabolic abnormalities were different. While English proficiency was not associated with high triglycerides or diabetes, those who reported speaking English "so-so" were at 0.70 times lower risk for hypercholesterolemia compared to those speaking English "fluently or well," accounting for all else. This protective association was not as strong for those speaking English "poorly or not at all" compared to those speaking English "fluently or well." Other research has noted that English proficiency measures a different aspect of acculturation than length of time lived in the US [38, 39]. While those who have lived longer in the US have likely had greater exposure to a US context than those who lived in the US for a shorter time, English proficiency captures linguistic adjustment to the main language used in the US. Asian immigrants who have lived in the US for many years may maintain low English proficiency if they are able to rely on Asian language-speaking family or community members for resources and support [40].

English proficiency may also be an indicator of past experience prior to immigration, including exposure to English language education and culture while in the country of origin. This may explain why English proficiency is not consistently associated with metabolic abnormalities as compared to time lived in the US. Nevertheless, greater English proficiency may also lead to more interaction with non-Asian members of US society, which could expose Asian Americans to higher levels of discrimination or stress, which could then impact health [25]. It is also possible that those who speak English fluently or well are more likely to be diagnosed and treated by a doctor compared with Asian immigrants who only speak some English [41]. In our sample, people who spoke English fluently/well had the highest rate of private health insurance (79%) and the lowest rate of having no insurance (9%). Even those with insurance may lack appropriate communication with their health care providers. This might explain some of the association between "so-so" English proficiency and less risk of hypercholesterolemia, which was partly based on self-reported diagnosis. More research is needed to examine the associations and mechanisms between English proficiency and metabolic abnormalities.

Our third hypothesis stated that the association between acculturation and metabolic abnormalities would vary by gender, Asian subgroup, or income. Our results showed partial support for this hypothesis; the associations between years in the US, diabetes, and hypercholesterolemia varied by income level. For those earning less than $40,000 per year, living in the US for a shorter amount of time was associated with 0.41 times lower prevalence of diabetes compared to those living in the US longer. This may be due to the wide availability of cheap, high caloric foods that are high in refined carbohydrates [42]. Chinese and Korean immigrants with higher incomes may be able to better avoid these types of foods, regardless of how long they have lived in the US [43]. This moderation effect was different for hypercholesterolemia. Living in the US for a shorter amount of time was associated with 0.71 times lower prevalence of hypercholesterolemia compared to those living in the US longer, only among those earning $40,000 per year or more. For those with higher income, living longer in the US may be a risk factor for Chinese and Korean American immigrants being able to consume richer foods that are high in cholesterol. Future studies may examine how dietary acculturation occurs over time for Chinese and Korean immigrants, and how this varies by income level [4, 6, 25].

Living in the US longer may lead to changes in diets and exercise habits that increase risk for diabetes and dyslipidemia [15, 42]. These dietary changes may be attributable to different foods being available in the US in comparison to home countries, such as foods that are high in fats and sugars [44, 45]. However, studies have noted that there is a paucity of prospective studies among East Asian immigrants that explain how dietary acculturation occurs and how it may contribute to metabolic abnormalities [44, 46]. On the other hand, research on acculturation and exercise among immigrants is mixed, with some studies showing that higher acculturation is associated with more healthy exercise habits [47, 48]. Therefore, other pathways linking length of stay in the US and metabolic abnormalities should be explored in future research, including the potential mediating roles of health behaviors, psychosocial stress, and sleep health.

The few studies on the associations between acculturation and diabetes and hypercholesterolemia among East Asian Americans have been mixed. While one study among Chinese immigrants in Australia found length of residence to be positively associated with diabetes [9], other US-based studies have found no such association in samples of primarily East Asian American immigrants [16, 18]. To our knowledge, no study has examined the association between acculturation and hypercholesterolemia among East Asian immigrants in the US. Those studies that have examined this association among immigrants in the US broadly have in general found no association between length of residence and hypercholesterolemia [18, 20]. Only one study found longer years in the US was associated with higher total cholesterol in a multiethnic cohort [19]. Our findings suggest that one possible reason for the lack of associations between acculturation, diabetes, and hypercholeterolemia is that these associations vary by factors such as socioeconomic status. Our study is the first to our knowledge to find associations between acculturation and these outcomes that varied by income.

There are limitations to this study which should be noted. The data are cross-sectional so it is not possible to determine causation in the associations between acculturation measures and metabolic abnormalities. The sample consisted of Chinese and Korean immigrants in the Baltimore-Washington DC Area recruited from physicians' clinics. The original study purpose was to increase colorectal cancer screening for Chinese and Korean immigrants between 50 and 75 years-old, so the sample is not representive of the population of Chinese and Korean immigrants at all ages. Participants were not randomly selected, and therefore, the sample is subject to selection bias. Furthermore, the sample is not representative of other Asian subgroups, subsequent generations, and East Asian Americans broadly in other parts of the US. More research is needed to illuminate how acculturation affects cardiovascular disease risk in other Asian American subpopulations as well. As such, these findings should be interpreted with caution. An additional limitation is that the blood samples were only measured once and were taken at different times of the day for various participants. Therefore, we relied on a single non-fasting (random) blood test for participants' biomarker measurements, which is not enough to determine a medical diagnosis for diabetes or hypercholesterolemia. We also relied on self-reported data from participants on whether they had been diagnosed with diabetes and hypercholesterolemia, which may be subject to reporting bias due to forgetting or wanting to hide an undesirable diagnosis from researchers. Nevertheless, this study benefited from combining both objective (blood measurement) and subjective (self-reported) measures of metabolic abnormalities in a sample consisting of Chinese and Korean American immigrants. Lastly, our study only captured two proxies for acculturation—years lived in the US and English speaking proficiency. Other more in-depth studies should examine other relevant dimensions of acculturation, such as social interactions with people of the same race or ethnicity, the language in which people consume media, and preferences for types of diets typically eaten. Despite these limitations, the recruitment and survey collection tools were available in Mandarin, Korean, and English, maximizing cultural relevance of the current study.

This study demonstrates that proxy measures of acculturation, including length lived in the US and English proficiency, likely capture different aspects of acculturation in relationship to health. Overall, the findings suggest that lower level of acculturation is protective for the cardiometabolic health of Chinese and Korean American immigrants. Furthermore, the effect of acculturation on cardiometabolic disease seems to vary by income level. Future studies should carefully consider what measures of acculturation are truly capturing in relationship to health outcomes. Doing so will help to illuminate the relationship between acculturation and health for immigrant groups.

Author Contribution Brittany N. Morey and Sunmin Lee contributed to the study conception and design. Data analysis was performed by Yuxi Shi and Soomin Ryu. Literature review was conducted by Hye Won Park. The first draft of the manuscript was written by Brittany N. Morey, Soomin Ryu, and Yuxi Shi. Sunmin Lee obtained funding, acquired data, provided critical comments for revision, and supervised all aspects of this research. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Ethics Approval This study was performed in line with the principles of the Declaration of Helsinki. Ethics approval was granted by the Institutional Review Boards of University of Maryland, College Park and the University of California, Irvine.

Consent to Participate Informed consent was obtained from all individual participants included in the study.

Competing Interests The authors declare no competing interests.

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