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The Relationship of Acculturation to Cardiovascular Disease Risk Factors among U.S. South Asians: Findings from the MASALA Study

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Abstract

Aim: We investigated the association between acculturation strategies and cardiometabolic risk among South Asian(SA) immigrants in the US.

Methods: In this cross-sectional analysis of data from 849 SA participants in the Mediators of Atherosclerosis in SAs Living in America (MASALA), we performed multidimensional measures of acculturation to categorize the participants into three acculturation classes: *separation*(preference for SA culture), *assimilation*(preference for US culture), and *integration*(similar preference for both cultures). Differences in glycemic indices, blood pressure, lipid parameters and body composition by acculturation strategy were examined.

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Results: Women in the *integration* class had the lowest prevalence of diabetes (16.4%), prediabetes (29.7%), fasting and 2-hr glucose compared to women in the *separation* class with the highest prevalence of diabetes (29.3%), prediabetes (31.5%), fasting and 2-hr glucose and 2-hr insulin (all $p<0.05$). Women in the *assimilation* class had significantly lower triglycerides, BMI, and waist circumference and higher HDL compared to women in the *separation* class after adjusting for age, study site, and years in the US. After additionally accounting for socioeconomic/lifestyle factors, women in the *assimilation* class had significantly lower triglyceride and higher HDL levels compared to women in the *separation* class ($p<0.01$). There was no significant association between acculturation strategies and cardiometabolic risk in SA men.

Conclusion: SA women who employed an *assimilation* or *integration* strategy had a more favorable cardiometabolic profile compared to women using a *separation* strategy. Future research should investigate the behavioral and psychosocial pathways linking acculturation strategies with cardiometabolic health to inform preventive interventions among SAs living in America.

Keywords

Acculturation; cardiovascular disease risk factors; cardiometabolic health; immigration; assimilation; integration; separation

INTRODUCTION

The prevalence of cardiovascular disease (CVD) risk factors including diabetes, hypertension, dyslipidemia, and obesity is rising at alarming rates in South Asia.¹⁻³ Immigrants from South Asian (SA) countries (i.e. India, Pakistan, Bangladesh, Sri Lanka, and Nepal) became the fastest-growing ethnic group in the United States (US) between 2000 and 2010, and there are close to 4.9 million SAs in the US.^{4, 5} South Asian immigrants have a higher prevalence of CVD risk factors and greater cardiovascular mortality compared to local populations and immigrants of other ethnic groups.⁶⁻¹¹ Furthermore, SA immigrants develop cardiometabolic diseases at a younger age and a lower BMI than individuals of other ethnic groups.^{10, 12, 13}

Similar to other immigrants, South Asians experience a process of acculturation whereby changes in cultural and psychosocial behaviors take place as they interact with members of different cultural groups and social structures in the host country and adapt to a new culture and environment.¹⁴ The impact of acculturation on cardiometabolic health has been examined among various ethnic groups, but prior work has been limited by its overreliance on simple unidimensional proxy measures of acculturation (e.g. English fluency and years in the US) which do not account for the multiple dimensions and complex nature of the impact of acculturation on health. Using these proxy measures, greater acculturation (i.e. *assimilation*) has been associated with an increased prevalence of various CVD risk factors in Japanese, Chinese, Hispanic, European, and Black immigrants in the US.¹⁵⁻²¹ The worse cardiometabolic profile in those who migrated from low-income to high-income countries compared to those who remained in their low-income home countries has been attributed to possibly adopting unhealthy behaviors related to dietary pattern (e.g. high-carbohydrate and/or fat intake), physical activity (e.g. sedentary life), psychosocial factors (e.g. depression or chronic stress), or combination of more than one of these factors that are more prevalent

in most high-income countries.^{22–24} For example, a higher consumption of animal protein, animal and vegetable fat, and simple carbohydrates along with lower physical activity have been found in Japanese immigrants in the US compared to Japanese living in Hiroshima.²¹ These lifestyle changes were associated with unfavorable changes in lipids, blood pressure, BMI, and carotid intima-media thickness in this study. Acculturation, however, is widely variable among immigrants and depends in part on the differences in health behaviors between the host country and country of origin. It is possible that some immigrants may adopt healthier behaviors from the host country that would lower their risk of CVD.^{25–27} Hence, the use of a multidimensional model of acculturation is needed to better characterize the impact of acculturation on cardiometabolic health and capture domains of this process that may not be apparent with the use of the traditional proxy measures of acculturation. Moreover, sex differences in the degree of assimilation to the host culture after migration, as well as heterogeneity by sex in the association of acculturation and CVD risk factors have been reported in various ethnic groups.^{20, 28–30}

In this study, we sought to examine the association between acculturation strategies, using several cultural and behavioral indicators of acculturation, and CVD risk factors among SA immigrants in the US. We used data from the Mediators of Atherosclerosis in South Asians Living in America (MASALA) study that utilized twelve indicators of acculturation to identify three acculturation strategies: *assimilation*, *integration*, and *separation*.³¹ We hypothesized that by potentially adopting unhealthy behaviors that are prevalent in the US, SA immigrants using the *assimilation* and *integration* strategies (i.e. stronger preference of US culture over SA culture) would have a higher prevalence of CVD risk factors than South Asians using the *separation* strategy (i.e. stronger preference of SA culture over US culture). We also hypothesized that the association between acculturation and CVD risk factors would vary by sex among SA immigrants.

METHODS

Study design and participants

We conducted a cross-sectional analysis of data from the MASALA study, a community-based cohort of SA men and women from two clinical sites (San Francisco Bay Area at the University of California, San Francisco (UCSF) and the greater Chicago area at Northwestern University (NWU)). MASALA enrolled 906 participants (98% foreign-born) between October 2010 and March 2013. The detailed study design and objectives of the MASALA study have been previously described.³² In brief, individuals were eligible for the MASALA study if they were aged 40 to 84 years, self-identified as having SA ancestry (defined as having 3 or more grandparents born in India, Pakistan, Nepal, Bangladesh, or Sri Lanka), and free from physician-diagnosed CVD. All visits were conducted by trained bilingual study staff and all consent forms were translated into Hindi and Urdu. The institutional review boards at the University of California, San Francisco (UCSF) and Northwestern University (NWU) approved the MASALA study protocol, and all study participants provided written informed consent.

For this analysis, we excluded 31 individuals who were missing data on one or more variables used in the acculturation analysis, 7 individuals with missing data on diabetes status, and 19 individuals who were born in the US (final n=849).

Acculturation strategies

Using twelve indicators of acculturation, SA immigrants in the MASALA study have been previously shown to use one of the following three acculturation strategies: *Separation* (preference of SA culture over US culture); *Integration* (similar preference for SA and US cultures); and *Assimilation* (preference of US culture over SA culture). A detailed description of the methodology used to identify the acculturation strategies employed by MASALA participants has been previously published.³¹ In brief, respondents were asked to report how much they wish the following traditions from South Asia would be practiced in America (1 = absolutely- 5 = not at all): (1) performing religious ceremonies or rituals; (2) serving SA sweets for ceremonies or rituals; (3) fasting on specific occasions; (4) living in a joint family; (5) having an arranged marriage; (6) having a staple diet of chapatis, rice, daal, vegetables, and yogurt; and (7) using spices for healing and health. Next, respondents were asked to report how often they fast (1= two or three times per week- 6= almost never or never), what foods they normally eat at home and in restaurants (1= only SA food- 6= never eat at home/in restaurants), how often their family shops at SA grocery stores or markets (1= two or three times per week- 5= almost never or never), and which country or culture most of their friends belong to (1= only SA- 5= only other ethnic groups). Latent class analysis (LCA) was used to identify acculturation strategies: “*separation*” having a high preference for SA culture, “*assimilation*” having the least preference, and “*integration*” having an intermediate preference.³¹

Assessment of CVD risk factors

Participants were assessed for traditional CVD risk factors including dysglycemia, dyslipidemia, hypertension, and obesity.

Blood samples were collected after a 12-hour overnight fast. Total cholesterol, triglyceride, and high-density lipoprotein (HDL) cholesterol levels were analyzed by enzymatic methods, and low-density lipoprotein (LDL) cholesterol concentrations were calculated. Dyslipidemia was defined as having a total cholesterol of ≥ 200 mg/dl, triglyceride of ≥ 150 mg/dl, HDL < 40 mg/dl in men or < 50 mg/dl in women, or using a cholesterol-lowering medication. A 75-g oral glucose tolerance test was performed for participants who were not taking glucose-lowering medications and blood samples were drawn 2 hours after the glucose challenge. Fasting plasma glucose (FPG) and 2-hour post challenge glucose were measured using a hexokinase method (Quest Labs, San Jose, CA). Fasting serum insulin was measured by the sandwich immunoassay method (Elecsys 2010, Roche Diagnostics). The homeostasis model assessment (HOMA)-IR was used to measure IR and calculated as $[\text{Insulin}_0 (\mu\text{IU/mL}) / \text{Glucose}_0 (\text{mmol/L}) / 22.5]$, and HOMA-b was used to measure β -cell function and was calculated as $[20 \times \text{Insulin}_0 (\mu\text{IU/mL}) / \text{Glucose}_0 (\text{mmol/L}) - 3.5]$.³³ We excluded participants taking glucose-lowering medications from the analyses of HOMA-IR and HOMA-B. Diabetes and prediabetes were defined according to the American Diabetes Association guidelines.³⁴

Three seated blood pressure measurements were obtained after resting in a seated position for 5 minutes as previously reported.³² Hypertension was defined as a systolic blood pressure of ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg or use of a blood pressure lowering medication.

Participant weight and waist and hip circumferences were measured and body mass index (BMI) was calculated as previously described.³² Obesity was defined according to the WHO Asian BMI cut-off point of BMI ≥ 27.5 kg/m².³⁵

Abdominal visceral, subcutaneous, and intermuscular fat areas were calculated using abdominal computed tomography scans (CT, Philips Medical Systems, Andover, MA, USA; Toshiba Medical Systems, Tustin, CA, USA; Siemens Medical Solution, Malvern, PA, USA) as previously reported.^{36,37} The relationship of hepatic fat content and hepatic attenuation is an inverse one with higher hepatic attenuation implying lower fat content.

Covariates

All participants completed a detailed questionnaire to ascertain sociodemographic information, medical history, family history, medication use, cultural practices, and behaviors. Dietary intake over the previous year was assessed using the Study of Health Assessment and Risk in Ethnic Groups (SHARE) food frequency questionnaire, which was created and validated among SAs in Canada.³⁸ Physical activity was assessed using the Typical Week's Physical Activity Questionnaire.³⁹ Total physical activity included intentional exercise, occupational activities, volunteer activities, household chores, yardwork, child/adult care, transportation, and leisure activities. Intentional exercise included walking for exercise, dancing, team sports, dual sports, individual activities, moderate conditioning activities, and heavy conditioning activities. Tobacco use and alcohol consumption were determined by questionnaires. Several psychosocial scales were administered including the Center for Epidemiologic Studies Depression Scale (CES-D).⁴⁰

Statistical Analyses

Variable distributions were examined for normality using the Shapiro-Wilk test and visual examination of histograms. The non-normally distributed variables of FPG, 2-hour glucose, HDL, and triglyceride were presented as medians and interquartile ranges (IQR) and HOMA-IR was appropriately transformed. Baseline characteristics were compared by acculturation class using pairwise comparison (i.e. *separation* vs *integration* and *separation* vs *assimilation*). Participant characteristics were stratified by sex and were compared using *t*-tests for continuous variables and chi-squared tests of homogeneity for categorical variables. Non-normally distributed variables were compared using Kruskal–Wallis test. Multivariable linear regression analyses were used to determine which acculturation strategy classes were associated with the various CVD risk factors in unadjusted models, after controlling for age and study site (Model 1), additionally adjusting for socioeconomic factors such as education level, family income, employment, country of birth, marital status, religious affiliation, years lived in the US, and medical insurance (Model 2), and after additionally adjusting for behavioral and psychosocial factors such as total physical activity, total exercise, total caloric intake, depression, smoking, and alcohol status (Model 3).

We tested the effect modification of sex on the relationship between acculturation and CVD risk factors by including an interaction term (sex \times acculturation class). The unadjusted interaction terms were significant for HDL, triglyceride, and BMI; as well as the fully adjusted interaction terms for HDL and triglyceride (all p values <0.05). Therefore, all data are presented stratified by sex. In addition, we performed a sensitivity analysis to evaluate the association between length of residence in the US and prevalence of CVD risk factors as this is a commonly used proxy measure of acculturation in literature. All significance testing was 2-tailed with α of 0.05, and data were analyzed using SAS (version 9.4; SAS Institute Inc, Cary, NC).

RESULTS

Sociodemographic and lifestyle-related factors by acculturation class

The study population included 849 participants, of whom 45.8% were women and 23.0% were in the *separation* class, 54.4% in the *integration* class, and 22.6% in the *assimilation* class. Majority of the study participants spoke English well or very well (87.2%), were born in India (85.3%) and were employed (70.4%). Table 1 shows the characteristics of the study participants by sex and acculturation class. Compared to those in the *separation* class, men and women in the *assimilation* and *integration* classes had a longer residence in the US; more education and higher income; were more likely to have insurance and speak English well or very well, and had lower CES-D scores. Men and women in the *assimilation* class had the highest total exercise per week and lowest caloric intake; whereas those in the *separation* class had the lowest total exercise per week and highest caloric intake.

Cardiovascular disease risk factors by acculturation class

Glycemic indices: Women in the *integration* class had the lowest prevalence of diabetes (16.4%) and prediabetes (29.7%) compared to women in the *separation* class who had the highest prevalence of diabetes (29.3%) and prediabetes (31.5%). Similarly, women in the *integration* class had significantly lower 2-hr glucose and insulin, compared to women in the *separation* class. Men, however, had no significant differences in any of the glycemic indices by acculturation class (Table 1, Figure 1 A, and Supplementary Figure 1).

Blood pressure: There were no significant differences in systolic or diastolic blood pressure by acculturation class among men or women (Supplementary Figures 2 A and B).

Lipid parameters: Triglycerides were significantly lower in women in the *assimilation* class versus the *separation* class (median(IQR): 99(65) versus 125(55) mg/dl, $p<0.01$) and HDL was significantly higher in the *assimilation* class versus the *separation* class (median(IQR): 58.5(20) versus 50(16) mg/dl, $p<0.01$). Similarly, women in the *integration* class had lower triglyceride and slightly higher HDL levels compared to those in the *separation* class ($p<0.01$ and 0.05 , respectively). Overall, no significant differences were noted in any of the lipid parameters by acculturation class in men (Figure 1 B, 1 C, and Supplementary Figure 2 C).

Weight and body composition: The prevalence of obesity was lowest among women in the *assimilation* class (26.5%), followed by the *integration* class (28.4%) and the *separation* class (48.9%) ($P<0.01$ for both: *assimilation* versus *separation* and *integration* versus *separation*) (Table 1). Similarly, BMI was significantly lower in women in the *assimilation* class versus the *separation* class ($p<0.01$); and in women in the *integration* class versus the *separation* class ($p<0.01$) (Figure 1 D). Furthermore, women in the *assimilation* and *integration* classes had significantly lower hip girth and pericardial fat compared to those in the *separation* class (Table 1 and Supplementary Figure 3 C). Men, however, had no significant differences in the prevalence of obesity, BMI, hip girth, or body fat composition by acculturation class (Figure 1 D and Supplementary Figure 3 B -D).

Cardiovascular disease risk factors by duration of residence in the US

With the exception of HDL and waist circumference, none of the differences seen in the CVD risk factors by acculturation class was seen when length of residence in the US was used as a proxy measure of acculturation (Supplementary Table 1). There were no significant differences in any of the glycemic indices, triglyceride or LDL levels, blood pressure, BMI, or body composition by length of residence in the US. However, women and men who lived in the US for 20 or more years had higher HDL levels (57 ± 14 mg/dl and 46 ± 11 mg/dl; respectively) compared to women and men who lived in the US for 10 to 19 years (52 ± 14 mg/dl, $p<0.01$ and 44 ± 11 mg/dl, $p=0.02$; respectively) and compared to those who lived in the US for less than 10 years (52 ± 11 mg/dl, $p=0.04$ and 42 ± 5 mg/dl, $p=0.21$; respectively). The differences in HDL by length of residence in the US were not statistically significant when adjusted for age in men; and only women lived in the US for 20 or more years had a significantly higher age-adjusted HDL levels compared to those who lived in the US for less than 10 years (data not shown).

Multivariable regression analyses

The results of the multivariable regression analyses examining the relationship between the acculturation classes and various CVD risk factors are shown in Tables 2 and 3. Compared to women in the *separation* class, women in the *integration* class had significantly lower FPG (-8.9 ± 2.9 mg/dl, $p<0.01$) and 2-hr glucose (-20.3 ± 7.1 mg/dl, $p<0.01$) in the unadjusted model. These differences were attenuated and became non-significant after adjusting for age, study site, years lived in the US, education level, family income, country of birth, marital status, religious affiliation, medical insurance, and employment (Model 2, Table 2). Compared to women in the *separation* class, women in the *assimilation* class had significantly lower triglyceride levels [-29.2 ± 7.2 mg/dl, $p<0.01$] and higher HDL levels [9 ± 1.9 mg/dl, $p<0.01$] in the unadjusted model. These differences remained significant in the fully adjusted Model 3 (Table 2). Finally, compared to women in the *separation* class, women in the *assimilation* class had significantly lower waist circumference [-2.9 ± 1.4 cm, $p=0.04$] and BMI [-1.5 ± 0.6 kg/m², $p=0.01$] in the unadjusted model. No significant differences by acculturation class were noted in any of the CVD risk factors among men (Table 3).

DISCUSSION

In contrast to prior studies, we found a relatively higher degree of preference for US culture over SA culture— represented by the *integration* and *assimilation* classes— to be associated with an overall healthier cardiometabolic profile among SA women in the US; but the differences in CVD risk factors by acculturation strategy were not significant in men. Furthermore, we identified healthier behaviors and psychosocial factors in men and women who employ the *assimilation* strategy compared to those who employ the *separation* strategy that include less caloric intake, more total exercise, and less depression symptoms. However, the differences in these behavioral and psychosocial factors across acculturation classes did not completely explain the healthier cardiometabolic profile among SAs who expressed a stronger preference for US culture over SA culture. The differences by acculturation class in HDL and triglyceride levels among women, for example, remained significant even after adjusting for demographic, socioeconomic, behavioral, and psychosocial factors that include caloric intake, total exercise, and depression symptoms. It is possible that unmeasured lifestyle, psychosocial factors, and contextual factors among women in the different acculturation classes may explain these findings.

The sex differences in the association between acculturation and CVD risk factors in our study is an important finding that warrants further attention. Only among women, did we find that a relatively higher degree of preference for US culture over SA culture was associated with lower prevalence of CVD risk factors. Similarly, another study reported that maintaining the original culture was associated with a greater BMI and waist circumference in immigrant women in the US from the former Soviet Union.⁴² However, the association between acculturation and diabetes has been shown to be stronger in men than women in other studies in Latinos and other ethnic groups.^{15, 28} It has been postulated that the negative impact of health-compromising behaviors, highly prevalent in high-income countries, may be offset by the Western social norms on body shape which endorse slim body shape and fitness especially among women.¹⁷ In support of this idea, one study reported that Mexican Americans who were overweight and less acculturated were less likely to perceive themselves as overweight and to have tried to lose weight compared to those who were more acculturated.⁴³ Therefore, it is possible that SA women may adopt healthier behaviors and improved health knowledge and attitude as they integrate or assimilate in the US. It has also been proposed that women tend to adapt to the cultural norm of the host country more quickly than men; and it is possible that SA women may be influenced by some of the health-promoting behaviors in the US such as leisure-time physical activity more quickly than men⁵². It is also possible that differences in health beliefs and perception, knowledge about disease risk and prevention, and attitudes towards CVD risk factors, and psychosocial factors may exist across acculturation classes and could potentially explain the differences in CVD risk factors observed in our study. Future research should explore these potential pathways linking acculturation strategies with CVD risk factors in SA women.

Previous studies examining the association of acculturation and CVD risk factors have been inconclusive. For example, assimilation to the US has been associated with poorer health behaviors and increased risk of diabetes, hypertension, and coronary artery disease in many studies of other immigrant groups.^{16–18, 44–47} Duration of residence in the US and/or

English language proficiency have been used as surrogate markers of acculturation in many of these studies. In contrast, a smaller number of studies linked higher degree of acculturation with positive health behaviors and lower risk of diabetes, obesity, and other CVD risk factors.^{29, 42, 48–50} The inconsistency in these results is partly due to differences in country of origin and ethnicity, reasons for and context of migration, and, importantly, reliance on surrogate markers of acculturation that do not account for the multidimensional nature of acculturation. In fact, the use of length of residence in the US as a proxy measure of acculturation in our study failed to capture most of the differences in CVD risk factors observed with the use of the multidimensional acculturation model. Furthermore, participants in the *assimilation* and *integration* classes in our study had a healthier cardiometabolic profile despite having more years of residence in the US compared to those in the *separation* class. These findings highlight the advantage of using an expanded model of acculturation when studying the impact of acculturation on cardiometabolic health. This is especially true for SAs in the MASALA study because over 70% of them have been in the US for more than 20 years and speak English well or very well. Similar findings have been recently shown in Ghanaian and Nigerian-born African immigrants in the US; where those who employ an *integration* strategy were found to have lower CVD risk, despite having a longer duration of residence in the US, compared to those who had more traditional beliefs and behaviors.²⁹

A major strength of our study is that instead of relying on traditional proxy measures of acculturation such as years in the US or English language proficiency, we used a multidimensional model of acculturation that accounts for attitude about the practice of SA traditions in the US, frequency of fasting, food normally eaten at home and in restaurants, frequency of shopping in SA markets, and ethnic composition of friendship networks. Furthermore, the large community-based sample along with the comprehensive assessment of acculturation, CVD risk, lifestyle and behavioral factors in our study allowed us to identify the potential impact of acculturation strategies on CVD risk factors that is not apparent with the use of traditional proxy measures of acculturation. The latter finding has implications for future studies examining the health consequences of acculturation in SA immigrants, as well as immigrants of other racial/ethnic groups, living in high-income countries as our multidimensional model of acculturation can be adopted in those studies.

The limitations of our study include the cross-sectional nature that precludes us from making causal inferences as we are unable to ascertain temporal order between acculturation strategies and CVD risk factors. The MASALA study recruited participants from two specific geographic regions, the San Francisco Bay and great Chicago areas, which may not represent all SAs immigrants in the US. However, similarity of the MASALA population to the US Census 2010 South Asians data has been reported.³² Consistent with waves of SA immigration to the US, a majority of the MASALA study participants were Asian Indians, have lived in the US for over 20 years, speak English well or very well, and had a high socioeconomic status which limits the generalizability of our results. These, and other contextual factors, influence how immigrants acculturate into US society.⁵¹ It is possible that we have not captured residual confounding factors that may explain the linkage between acculturation strategies and CVD risk factors in SA immigrants. Finally, we treated latent class membership as an observed variable where respondents were assigned to a single

acculturation class based on their most likely class assignment. This approach does not account for uncertainty in latent class assignment.

In conclusion, our findings suggest that SA immigrant women who employ an *assimilation* or *integration* strategy have a more favorable cardiometabolic profile compared to women using a *separation* strategy. Therefore, programs targeting the prevention and management of CVD risk factors among SA immigrants should be culturally tailored to account for differences in acculturation strategy and sex; and focus on promoting the adoption and retention of healthy lifestyle and behaviors after arrival in the US. Future research should investigate the behavioral, psychosocial, and contextual pathways linking acculturation strategies with cardiometabolic health among SA immigrants and further explore the differences in the impact of acculturation strategies in women versus men and the potential incorporation into prevention interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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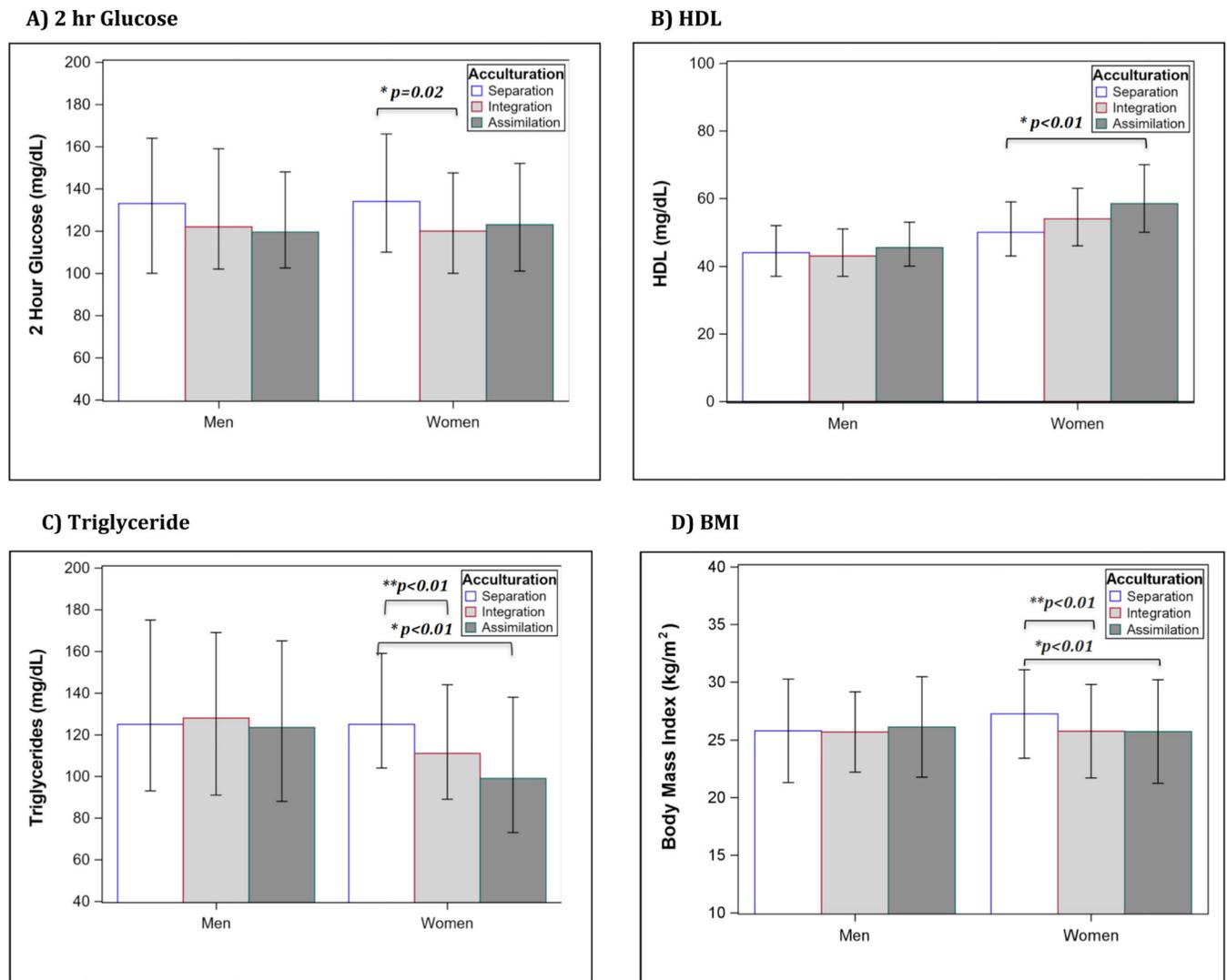


Figure 1:

A) 2-hour glucose levels were similar in women in the assimilation class [median (IQR): 123 (51) mg/dl, $p=0.09$] compared to women in the separation class [134 (56) mg/dl]. *Women in the integration class had significantly lower levels of 2-hour glucose [median (IQR): 120 (47.5) mg/dl, $p=0.02$] compared to women in the separation class. 2-hour glucose levels were similar in men in the separation, integration, and assimilation classes [median (IQR): 133 (64), 122 (57), and 119.5 (45.5) mg/dl, respectively; all $p>0.05$]. **B)** *HDL levels were higher in women in the assimilation group [median (IQR): 58.5 (20) mg/dl, $p<0.01$] compared to women in the separation class [50 (16) mg/dl]. Women in the integration class had a slightly higher HDL level [median (IQR): 54 (17) mg/dl, $p=0.05$] compared to women in the separation class. HDL levels were similar in men in the separation, integration, and assimilation classes [median (IQR): 44 (15), 43 (14), and 45.5 (13) mg/dl, respectively; all $p>0.05$]. **C)** *Triglyceride levels were lower in women in the assimilation group [median (IQR): 99 (65) mg/dl, $p<0.01$] compared to women in the separation class [125 (55) mg/dl]. **Women in the integration class also had a lower

triglyceride level [111 (55) mg/dl, $p<0.01$] compared to women in the separation class. Triglyceride levels were similar in men in the separation, integration, and assimilation classes [median (IQR): 125 (82), 128 (78), and 123.5 (77) mg/dl, respectively; all $p>0.05$].

D) *Significantly lower BMI in women in the assimilation group [mean (SD) 25.7 (4.5) kg/m², $p<0.01$] compared to women in the separation class [27.3 (3.8) kg/m²].

**Significantly lower BMI in women in the integration class [25.8 (4.1) kg/m², $p<0.01$] compared to women in the separation class. Similar BMI in men in the separation, integration, and assimilation classes [25.8 (4.5), 25.7 (3.5), and 26.1 (4.3) kg/m², respectively].

Table 1:

Participant Characteristics by Acculturation Class and Sex (n=849)

Characteristic	All n=849	Men (n=460)			Women (n=389)		
		Separation n=103 (22%)	Integration n=267 (58%)	Assimilation n =90 (20%)	Separation n=92 (24%)	Integration n=195 (50%)	Assimilation n=102 (26%)
Sociodemographic Characteristics							
Age, mean (SD), years	55.4 (9.3)	56.7 (9.7)	56.1 (9.8)	55.7 (10.3)	54.4 (9.2)	54.2 (8.2)	54.9 (8.8)
NWU study site	382 (45.0)	63 (61.2)	127 (47.6) ^a	31 (34.4) ^b	48 (52.2)	78 (40.0)	35 (34.3) ^b
Married, n (%)	780 (91.9)	103 (100)	259 (97.0)	83 (92.2) ^b	77 (83.7)	174 (89.2)	84 (82.4)
Religion, n (%)							
Hinduism/Jainism	633 (74.6)	72 (69.9)	212 (79.4) ^a	59 (65.6) ^b	60 (65.2)	163 (83.6) ^a	67 (65.7) ^b
Other religion	168 (19.8)	30 (29.1)	47 (17.6) ^a	12 (13.3) ^b	32 (34.8)	31 (15.9) ^a	16 (15.7) ^b
No religious affiliation	48 (5.7)	1 (1.0)	8 (3.0) ^a	19 (21.1) ^b	0	1 (0.5) ^a	19 (18.6) ^b
Birthplace, n (%)							
India	724 (85.3)	81 (78.6)	232 (86.9) ^a	80 (88.9) ^b	73 (79.3)	171 (87.7) ^a	87 (85.3) ^b
Other	125 (14.7)	22 (21.4)	35 (13.1) ^a	10 (11.1) ^b	19 (20.7)	24 (12.3) ^a	15 (14.7) ^b
Years lived in the US, mean (SD)	27.0 (10.8)	24.5 (11.3)	27.0 (10.4) ^a	31.8 (10.4) ^b	22.6 (10.7)	26.8 (10.4) ^a	29.9 (10.5) ^b
Percent of life in US, mean (SD), %	48.5 (16.5)	43.4 (18.6)	47.8 (15.1) ^a	56.9 (15.4) ^b	41.7 (17.5)	48.8 (15.8) ^a	53.6 (15.0) ^b
English language proficiency, n (%)							
Speak English poorly or fairly	109 (12.8)	30 (29.1)	17 (6.4) ^a	1 (1.1) ^b	38 (41.3)	20 (10.3) ^a	3 (2.9) ^b
Speak English well or very well	740 (87.2)	73 (70.9)	250 (93.6) ^a	89 (98.9) ^b	54 (58.7)	175 (89.7) ^a	99 (97.1) ^b
Education, n (%)							
Less than bachelor's degree	97 (11.4)	19 (18.4)	22 (8.2) ^a	5 (5.5) ^b	32 (34.8)	11 (5.6) ^a	8 (7.8) ^b
Bachelor's degree	247 (29.1)	39 (37.9)	60 (22.5) ^a	16 (17.8) ^b	30 (32.6)	77 (39.5) ^a	25 (24.5) ^b
More than bachelor's degree	505 (59.5)	45 (43.7)	185 (69.3) ^a	69 (76.7) ^b	30 (32.6)	107 (54.9) ^a	69 (67.7) ^b

Characteristic	All n=849		Men (n=460)		Women (n=389)		
	Separation n=103 (22%)	Integration n=267 (58%)	Assimilation n=90 (20%)	Separation n=92 (24%)	Integration n=195 (50%)	Assimilation n=102 (26%)	
Annual family income, n (%)							
<\$100,000	314 (37.0)	93 (34.8) ^a	15 (16.7) ^b	61 (66.3)	55 (28.2) ^a	27 (26.5) ^b	
\$100,000 to \$200,000	291 (34.3)	107 (40.1) ^a	35 (38.9) ^b	18 (19.6)	79 (40.5) ^a	31 (30.4) ^b	
>\$200,000	244 (28.7)	67 (25.1) ^a	40 (44.4) ^b	13 (14.1)	61 (31.3) ^a	44 (43.1) ^b	
Insurance status, n (%)							
Insured	780 (91.9)	249 (93.3) ^a	90 (100) ^b	75 (81.5)	183 (93.8) ^a	100 (98.0) ^b	
Not Insured	69 (8.1)	18 (6.7) ^a	0 ^b	17 (18.5)	12 (6.2) ^a	2 (2.0) ^b	
Occupation, n (%)							
Unemployed	135 (15.9)	11 (4.1)	2 (2.2)	35 (38.0)	58 (29.7)	22 (21.6) ^b	
Employed	598 (70.4)	215 (80.5)	75 (83.3)	49 (53.3)	118 (60.5)	63 (61.8) ^b	
Retired	116 (13.7)	41 (15.4)	13 (14.4)	8 (8.7)	19 (9.7)	17 (16.7) ^b	
CES-D depression scale, mean (SD)	7.7 (7.1)	7.1 (6.6) ^a	5.1 (4.5) ^b	9.9 (8.7)	8.1 (7.3)	7.1 (6.8) ^b	
Lifestyle and Behavioral Factors							
Total physical activity, mean (SD), MET-min/week	10057 (4031)	9518 (3410)	9410 (2848)	10680 (4706)	10452 (4317)	10382 (4353)	
Total exercise, median (IQR), MET-min/week	945 (1523)	1020 (1418)	1365 (1755) ^b	630 (1076)	825 (1605) ^a	1260 (1845) ^b	
Total caloric intake, median (IQR), Kcal	1613 (654)	1705 (700)	1513 (642) ^b	1573 (537)	1527 (564)	1454 (627)	
Smoking, n (%)							
Never	701 (82.6)	188 (70.4)	61 (67.8)	91 (98.9)	191 (97.9)	94 (92.2)	
Former	119 (14.0)	63 (23.6)	23 (25.6)	1 (1.1)	2 (1.0)	6 (5.9)	
Current	29 (3.4)	16 (6.0)	6 (6.7)	0	2 (1.0)	2 (2.0)	
Alcohol use 1 drink/week, n (%)	277 (32.6)	116 (43.4) ^a	64 (71.1) ^b	5 (5.4)	32 (16.4) ^a	37 (36.3) ^b	

Abbreviations: NWU, Northwestern University.

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* Differences by acculturation class were examined using t tests and pairwise comparison (i.e. *separation* vs integration and *separation* vs *assimilation*); categorical variables were examined using chi-squared tests of homogeneity. Testing was performed on log transformed variables when necessary to achieve normality.

^a Statistically significant difference ($p \text{ value} < 0.05$) between integration and separation classes.

^b Statistically significant difference ($p \text{ value} < 0.05$) between assimilation and separation classes.

Table 2: Cardiovascular Risk Factors and Body Composition by Acculturation Class and Sex (n=849)*

Characteristic	All n=849	Men (n=460)			Women (n=389)		
		Separation n=103 (22%)	Integration n=267 (58%)	Assimilation n =90 (20%)	Separation n=92 (24%)	Integration n=195 (50%)	Assimilation n=102 (26%)
Cardiovascular Risk Factors							
Glycemic status, n (%)							
Normal	348 (41.0)	31 (30.1)	93 (34.8)	37 (41.1)	36 (39.1)	105 (53.8) ^a	46 (45.1)
Prediabetes	282 (33.2)	40 (38.8)	95 (35.6)	28 (31.1)	29 (31.5)	58 (29.7) ^a	32 (31.4)
Diabetes	219 (25.8)	32 (31.1)	79 (29.6)	25 (27.8)	27 (29.3)	32 (16.4) ^a	24 (23.5)
Fasting glucose, median (IQR), mg/dl		101 (24)	99 (20)	97 (26)	94 (18)	94 (12)	95 (15)
Hemoglobin A1C, mean (SD), %	6.1 (0.9)	6.3 (1.0)	6.1 (0.9)	6.2 (1.0)	6.2 (1.2)	5.9 (0.5)	6.0 (0.7)
HOMA-B, mean (SD)	123.3 (90.2)	149.4 (151.0)	117.6 (84.4)	127.6 (95.6)	120.1 (68.9)	122.2 (65.0)	111.1 (65.5)
Fasting insulin, mean (SD), pmol/L	76.0 (85.0)	95.2 (117.7)	82.1 (117.1)	78.0 (49.4)	71.1 (41.3)	63.3 (36.9)	65.9 (50.8)
2-hr insulin, mean (SD), pmol/L	721.9 (628.3)	831.5 (518.1)	766.1 (643.0)	841.9 (956.1) ^b	805.0 (692.5)	619.4 (504.7) ^a	507.0 (340.9) ^b
Hypertension, n (%)	339 (39.9)	50 (48.5)	115 (43.1)	40 (44.4)	33 (35.9)	70 (35.9)	31 (30.4)
Dyslipidemia, n (%)	557 (65.6)	69 (67.0)	189 (70.8)	65 (72.2)	64 (69.6)	112 (57.4)	58 (56.9)
Total Cholesterol, mean (SD), mg/dl	187.2 (37.1)	181.8 (35.4)	181.4 (37.1)	182.5 (39.1)	195.0 (38.3)	192.4 (34.6)	194.8 (37.1)
Cholesterol-lowering medications, n (%)	254 (29.9)	35 (34.0)	88 (33.0)	40 (44.4)	24 (26.1)	37 (19.0)	30 (29.4)
Glucose-lowering medications, n (%)	142 (16.7)	25 (24.3)	51 (19.1)	18 (20.0)	15 (16.3)	17 (8.7)	16 (15.7)
Blood pressure-lowering medications, n (%)	253 (31.7)	42 (42.0)	83 (33.3)	34 (38.6)	23 (25.8)	45 (25.0)	26 (28.0)
Weight and Body Composition							
Obesity, n (%) ^f	250 (29.6)	32 (31.1)	67 (25.3)	24 (26.7)	45 (48.9)	55 (28.4) ^a	27 (26.5) ^b
Weight, mean (SD), Kg	69.9 (12.5)	73.7 (14.0)	74.4 (11.1)	76.1 (10.9)	66.1 (10.4)	63.8 (11.1) ^a	64.2 (11.7) ^b

Characteristic	All n=849	Men (n=460)		Women (n=389)		
		Separation n=103 (22%)	Integration n=267 (58%)	Assimilation n =90 (20%)	Separation n=92 (24%)	Integration n=195 (50%)
Hip girth, mean (SD), cm	102.8 (8.4)	101.9 (8.6)	102.5 (7.4)	101.7 (6.9)	105.6 (8.7)	102.1 (8.4) ^b
Waist-Hip ratio, mean (SD)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)
Subcutaneous fat, mean (SD), cm ²	234.8 (91.5)	208.0 (90.6)	217.4 (83.8)	210.3 (76.3)	274.5 (113.2)	253.3 (91.0)
Inter-muscular fat, mean (SD), cm ²	21.3 (8.6)	21.0 (8.6)	21.4 (9.7)	20.6 (8.2)	21.8 (8.4)	22.4 (8.5)

* Differences by acculturation class were examined using *t* tests and pairwise comparison (i.e. *separation* vs integration and *separation* vs *assimilation*); categorical variables were examined using chi-squared tests of homogeneity. Testing was performed on log transformed variables when necessary to achieve normality.

[†] Obesity was defined using the WHO Asian BMI cut-off point of BMI 27.5 kg/m².

^a Statistically significant difference (*p* value<0.05) between integration and separation classes.

^b Statistically significant difference (*p* value<0.05) between assimilation and separation classes.

Table 3: Multivariable regression models of the relationship between cardiovascular disease risk factors and acculturation class in Women*

Characteristics	Unadjusted		Model 1		Model 2		Model 3	
	Beta	P-value	Beta	P-value	Beta	P-value	Beta	P-value
Fasting Glucose								
Separation	Ref		Ref		Ref		Ref	
Integration	-8.9 (±2.9)	<0.01	-7.0 (±2.9)	0.02	-4.7 (±3.2)	0.14	-2.8 (±2.8)	0.31
Assimilation	-4.9 (±3.3)	0.14	-2.5 (±3.4)	0.46	0.8 (±3.8)	0.84	0.8 (±3.4)	0.80
2 hr Glucose								
Separation	Ref		Ref		Ref		Ref	
Integration	-20.3 (±7.1)	<0.01	-20.3 (±7.1)	<0.01	-12.4 (±8.0)	0.12	-7.9 (±7.5)	0.29
Assimilation	-14.2 (±8.1)	0.08	-15.0 (±8.3)	0.07	-5.6 (±9.5)	0.55	2.5 (±9.1)	0.78
Systolic Blood Pressure								
Separation	Ref		Ref		Ref		Ref	
Integration	0.3 (±2.1)	0.88	1.0 (±2.0)	0.61	3.0 (±2.2)	0.19	3.0 (±2.2)	0.16
Assimilation	-2.7 (±2.4)	0.26	-2.2 (±2.3)	0.35	1.6 (±2.6)	0.53	1.2 (±2.6)	0.63
Diastolic Blood Pressure								
Separation	Ref		Ref		Ref		Ref	
Integration	1.1 (±1.2)	0.37	1.6 (±1.2)	0.21	1.9 (±1.4)	0.18	2.2 (±1.4)	0.12
Assimilation	-1.0 (±1.4)	0.48	-0.1 (±1.4)	0.92	1.3 (±1.6)	0.43	0.9 (±1.7)	0.60
Total cholesterol								
Separation	Ref		Ref		Ref		Ref	
Integration	-2.6 (±4.6)	0.56	-4.0 (±4.6)	0.39	2.7 (±5.2)	0.61	-2.2 (±4.9)	0.65
Assimilation	-0.2 (±5.2)	0.97	-2.4 (±5.4)	0.65	3.9 (±6.0)	0.52	1.7 (±5.8)	0.77
Triglycerides[†]								
Separation	Ref		Ref		Ref		Ref	
Integration	-20.5 (±6.4)	<0.01	-19.4 (±6.5)	<0.01	-19.3 (±7.5)	0.01	-18.2 (±7.5)	0.02
Assimilation	-29.2 (±7.2)	<0.01	-27.8 (±7.6)	<0.01	-25.4 (±8.7)	<0.01	-24.2 (±8.8)	<0.01
LDL								

Characteristics	Unadjusted		Model 1		Model 2		Model 3	
	Beta	P-value	Beta	P-value	Beta	P-value	Beta	P-value
Separation	Ref		Ref		Ref		Ref	
Integration	-1.5 (±4.0)	0.71	-2.4 (±4.1)	0.57	3.6 (±4.6)	0.44	-0.4 (±4.3)	0.93
Assimilation	-3.2 (±4.6)	0.48	-4.4 (±4.8)	0.36	0.7 (±5.4)	0.89	-0.2 (±5.2)	0.96
HDL [†]								
Separation	Ref		Ref		Ref		Ref	
Integration	3.1 (±1.7)	0.07	2.4 (±1.7)	0.16	3.2 (±1.9)	0.09	2.5 (±1.9)	0.18
Assimilation	9.0 (±1.9)	<0.01	7.7 (±2.0)	<0.01	8.4 (±2.2)	<0.01	7.3 (±2.2)	<0.01
Visceral Fat								
Separation	Ref		Ref		Ref		Ref	
Integration	-8.9 (±5.6)	0.11	-8.3 (±5.6)	0.14	-6.1 (±6.4)	0.34	-5.2 (±6.3)	0.41
Assimilation	-11.4 (±6.4)	0.07	-11.3 (±6.5)	0.08	-8.1 (±7.4)	0.28	-5.6 (±7.4)	0.45
Waist Circumference								
Separation	Ref		Ref		Ref		Ref	
Integration	-2.4 (±1.2)	0.05	-2.7 (±1.3)	0.03	-1.6 (±1.4)	0.26	-1.5 (±1.4)	0.28
Assimilation	-2.9 (±1.4)	0.04	-3.5 (±1.5)	0.02	-1.8 (±1.7)	0.28	-1.6 (±1.7)	0.35
BMI [†]								
Separation	Ref		Ref		Ref		Ref	
Integration	-1.5 (±0.5)	<0.01	-1.5 (±0.5)	<0.01	-1.0 (±0.6)	0.09	-0.9 (±0.6)	0.12
Assimilation	-1.5 (±0.6)	<0.01	-1.5 (±0.6)	0.01	-1.0 (±0.7)	0.16	-0.8 (±0.7)	0.23

* Beta coefficient ±SD except as indicated. The regression models compare levels of various cardiometabolic risk factors in women in the *integration* and *assimilation* classes to those in the *separation* class. All results are from linear regression models. **Unadjusted model**; **Model 1**: adjusted for age, study site, and years lived in the US; **Model 2 (socioeconomic factors)**: Model 1 + adjustment for education level, family income, country of birth, marital status, religious affiliation, medical insurance, and employment; **Model 3 (behavioral and psychosocial factors)**: Model 2+ adjustment for total physical activity, total exercise, total caloric intake, depression, smoking and alcohol status. Additional adjustment for the use of glucose-lowering, blood pressure-lowering, and lipid-lowering medications was performed in Model 3 when examining the relationship between acculturation class and (fasting and 2 hr glucose), (systolic and diastolic blood pressure), and (total cholesterol, triglycerides, LDL, and HDL); respectively.

[†] p-value for interaction by sex is <0.05

Multivariable regression models of the relationship between cardiovascular disease risk factors and acculturation class in men*

Table 4:

Characteristics	Unadjusted		Model 1		Model 2		Model 3	
	Beta	P-value	Beta	P-value	Beta	P-value	Beta	P-value
Fasting Glucose								
Separation	Ref		Ref		Ref		Ref	
Integration	-1.6 (±3.0)	0.59	-0.8 (±3.0)	0.80	-0.1 (±3.1)	0.98	1.2 (±2.6)	0.65
Assimilation	-1.9 (±3.7)	0.61	-0.3 (±3.8)	0.94	0.4 (±4.1)	0.92	1.0 (±3.6)	0.77
2 hr Glucose								
Separation	Ref		Ref		Ref		Ref	
Integration	-2.4 (±7.2)	0.74	-0.4 (±7.2)	0.96	9.3 (±7.7)	0.23	7.9 (±7.7)	0.31
Assimilation	-8.9 (±8.9)	0.32	-4.8 (±9.3)	0.60	6.9 (±10.1)	0.49	4.0 (±10.4)	0.70
Systolic Blood Pressure								
Separation	Ref		Ref		Ref		Ref	
Integration	1.5 (±1.7)	0.37	1.4 (±1.6)	0.39	1.2 (±1.7)	0.46	1.9 (±1.7)	0.27
Assimilation	0.6 (±2.1)	0.77	0.2 (±2.0)	0.93	-0.2 (±2.2)	0.93	0.1 (±2.3)	0.98
Diastolic Blood Pressure								
Separation	Ref		Ref		Ref		Ref	
Integration	1.9 (±1.0)	0.06	1.7 (±1.0)	0.10	2.0 (±1.0)	0.05	2.4 (±1.0)	0.02
Assimilation	0.3 (±1.3)	0.79	-0.3 (±1.3)	0.80	-0.1 (±1.4)	0.96	-0.1 (±1.4)	0.93
Total cholesterol								
Separation	Ref		Ref		Ref		Ref	
Integration	-0.4 (±4.3)	0.93	-0.3 (±4.3)	0.94	-0.3 (±4.5)	0.95	0.1 (±4.0)	0.97
Assimilation	0.7 (±5.3)	0.90	1.0 (±5.5)	0.86	1.4 (±5.9)	0.81	8.7 (±5.6)	0.12
Triglycerides[†]								
Separation	Ref		Ref		Ref		Ref	
Integration	-7.8 (±8.7)	0.37	-8.1 (±8.6)	0.35	-7.9 (±9.0)	0.38	-7.4 (±9.1)	0.42
Assimilation	3.2 (±10.8)	0.76	3.6 (±11.1)	0.74	6.9 (±11.9)	0.57	10.2 (±12.5)	0.41
LDL								

Characteristics	Unadjusted		Model 1		Model 2		Model 3	
	Beta	P-value	Beta	P-value	Beta	P-value	Beta	P-value
Separation	Ref		Ref		Ref		Ref	
Integration	1.1 (±3.8)	0.76	1.2 (±3.8)	0.76	0.9 (±3.9)	0.82	2.1 (±3.5)	0.56
Assimilation	-3.2 (±4.7)	0.50	-2.8 (±4.9)	0.57	-2.9 (±5.2)	0.58	5.3 (±4.9)	0.27
HDL[‡]								
Separation	Ref		Ref		Ref		Ref	
Integration	-0.9 (±1.2)	0.48	-0.8 (±1.2)	0.51	-0.2 (±1.3)	0.89	-0.6 (±1.3)	0.66
Assimilation	2.0 (±1.5)	0.19	2.0 (±1.6)	0.21	2.1 (±1.7)	0.21	1.8 (±1.7)	0.30
Visceral Fat								
Separation	Ref		Ref		Ref		Ref	
Integration	-10.8 (±7.1)	0.13	-11.2 (±7.1)	0.12	-7.4 (±7.4)	0.32	-7.5 (±7.4)	0.31
Assimilation	-11.2 (±8.7)	0.20	-12.3 (±9.1)	0.17	-6.4 (±9.7)	0.51	-4.8 (±10.0)	0.63
Waist Circumference								
Separation	Ref		Ref		Ref		Ref	
Integration	-0.9 (±1.1)	0.40	-0.9 (±1.1)	0.39	-0.2 (±1.2)	0.86	-0.2 (±1.1)	0.88
Assimilation	-1.2 (±1.4)	0.38	-1.3 (±1.4)	0.37	-0.1 (±1.5)	0.97	0.3 (±1.6)	0.87
BMI[‡]								
Separation	Ref		Ref		Ref		Ref	
Integration	-0.1 (±0.5)	0.81	-0.2 (±0.5)	0.67	0.0 (±0.5)	0.96	0.0 (±0.5)	0.93
Assimilation	0.3 (±0.6)	0.56	0.2 (±0.6)	0.79	0.5 (±0.6)	0.41	0.4 (±0.7)	0.50

* Beta coefficient ±SD except as indicated. The regression models compare levels of various cardiometabolic risk factors in men in the *integration* and *assimilation* classes to those in the *separation* class. All results are from linear regression models. **Unadjusted model, Model 1:** adjusted for age, study site, and years lived in the US; **Model 2 (socioeconomic factors):** Model 1 + adjustment for education level, family income, country of birth, marital status, religious affiliation, medical insurance, and employment; **Model 3 (behavioral and psychosocial factors):** Model 2 + adjustment for total physical activity, total exercise, total caloric intake, depression, smoking and alcohol status. Additional adjustment for the use of glucose-lowering, blood pressure-lowering, and lipid-lowering medications was performed in Model 3 when examining the relationship between acculturation class and (fasting and 2 hr glucose), (systolic and diastolic blood pressure), and (total cholesterol, triglycerides, LDL, and HDL); respectively.

[‡] p-value for interaction by sex is <0.05