

Immigrant Assimilation and BMI and Waist Size: A Longitudinal Examination Among Hispanic and Chinese Participants in the Multi-ethnic Study of Atherosclerosis

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Objective: US birth and longer length of US residence among the foreign-born have been linked to higher anthropometric measures. However, previous studies have been cross sectional and few have examined heterogeneity by ethnic group. Cross-sectional findings that show immigrant weight converging to US-born levels with longer time in the United States imply that immigrants' weight is increasing at a faster rate relative to US-born individuals. Prospective studies are necessary to confirm this pattern.

Design and Methods: Using longitudinal data from 1,486 Hispanic and 802 Chinese adults aged 45-84 years in the Multi-ethnic Study of Atherosclerosis, we examined whether foreign-born participants experienced greater increases in BMI and waist circumference (WC) than the US-born over a median follow-up of 5 years. We also investigated heterogeneity in these associations by Hispanic subgroup.

Results: Among Hispanics and Chinese, the foreign-born had a lower adjusted mean BMI and WC at baseline than the US-born, but there were no significant differences in BMI or WC change over time. There was heterogeneity by Hispanic subgroup: despite small baseline nativity differences in WC, foreign-born Mexican Hispanics had a greater annual mean increase in WC over time compared to US-born Mexican Hispanics (mean difference in annual change = 0.28 cm, $P = 0.03$). There were no nativity differences in the rate of WC increase over time among non-Mexican Hispanics. Foreign-born Mexican Hispanics also experienced a faster rate of WC increase compared to foreign-born non-Mexican Hispanics (mean difference in annual change = 0.24 cm, $P = 0.01$).

Conclusions: Longer time in the United States, examined prospectively, may only be linked to adverse anthropometric changes in some immigrant groups.

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Introduction

Over the past two decades, immigrants have represented a growing share of the US population (1). Their increasing presence will have implications for overall population health and healthcare costs. A better understanding of immigrant health patterns is important for the design of public health interventions.

A common finding in studies of immigrants is a lower prevalence of obesity relative to the US-born despite the comparatively low socioeconomic position of immigrants (2-6). However, longer length of US residence has been associated with higher weight in immigrants suggesting that over time, the weights of immigrants converge to the

levels observed among the US-born (7-10). Acculturation to US behavioral norms, such as poor diet and sedentary lifestyle, has been hypothesized to explain this relationship (11).

Existing research is primarily cross sectional, precluding examination of change over time. In cross-sectional studies, the effects of time in the United States may be conflated with cohort or age effects. Conclusions drawn from cross-sectional studies assume that the weights of newly arrived immigrant cohorts have remained relatively stable over time. However, variability in immigrant selection processes and greater exposure to Western lifestyle behaviors within sending countries may invalidate this assumption (12,13). Another challenge is separating the effects of longer US residence from those of age-related and secular increases in obesity (14,15). The cross-

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sectional observation that longer-term immigrants have higher BMI or waist circumference (WC) may merely be a function of secular trends in weight impacting all segments of society rather than an effect of longer time in the United States. Prospective data are thus critical to determine whether immigrants' weight is increasing at a rate faster than would be expected net of aging and period effects (16).

Although several studies have examined heterogeneity in these associations by race or ethnicity, data on various race or ethnic subgroups remain limited (6,17). Ethnic variation may be a function of exposures occurring within the countries of origin, and/or of features of the receiving environment. Most contemporary US immigrants come from Latin America and Asia (18); Mexican- and Chinese-origin individuals constitute the largest segments of the Hispanic and Asian populations in the United States, respectively (18,19). Pan-ethnic categorizations of Hispanics and Asians mask considerable heterogeneity in culture, immigration history, and health profiles. Relative to other Hispanic subgroups, for example, individuals of Mexican origin have been disproportionately impacted by obesity (20,21). Whether the weight of Mexican-origin Hispanics is differentially influenced by greater exposure to the US context relative to other Hispanics is unknown. Examination of these differences is important to better understand US immigrant health patterns.

Using longitudinal data from the Multi-ethnic Study of Atherosclerosis (MESA), we examined whether Hispanic and Chinese foreign-born (FB) participants experienced greater increases in BMI and WC over a median follow-up of 5 years relative to their US-born counterparts. We also explored heterogeneity in this association by Hispanic subgroup.

Methods and Procedures

MESA is a prospective cohort study designed to investigate risk factors for subclinical cardiovascular diseases (CVD). MESA design details are provided elsewhere (22). Briefly, participants aged 45-84 years, free of clinical CVD at baseline, were recruited from six sites (Baltimore, MD; Chicago, IL; Forsyth County, NC; Los Angeles County, CA; Manhattan, NY; St. Paul, MN). The cohort includes 6,814 self-identified white, African-American, Hispanic, and Chinese-American individuals. The baseline examination took place between 2000 and 2002. Participants attended three follow-up examinations 18-24 months apart. Analyses were restricted to Hispanic and Chinese participants because of small numbers of FB individuals in other race/ethnic groups.

Height (m) and weight (kg) (to calculate BMI [kg/m^2]) and WC (cm) were measured at all study visits using standardized procedures. For descriptive purposes, BMI was also dichotomized based on obesity status ($\text{BMI} \geq 30 \text{ kg}/\text{m}^2$); WC was dichotomized based on the World Health Organization's criteria for abdominal obesity (23). Although there is no clear consensus on the best anthropometric measure to use among older individuals, several studies show WC to be a better predictor of cardiovascular risk and mortality than BMI (24,25). Because of age-related changes in body composition, BMI comparisons across groups in older populations may be more likely to reflect variation in lean body mass than in fat mass, reducing the validity of BMI as a marker of adiposity (25). For these reasons, although we present results for both BMI and WC, we focus primarily on WC.

Nativity (US-born, FB), length of US residence (<15 years, 15-30 years, >30 years, missing), age (continuous, mean-centered at 63 years), sex,

race/ethnicity (Hispanic, Chinese), Mexican-origin ethnicity among Hispanics (yes/no), education (<high school, high school graduate, some college, college graduate), and family income within the past 12 months (13 categories: <\$5,000-\$100,000+) were obtained during the baseline interview. Baseline income was available for 97.6% of Hispanics and 99.3% of Chinese. When missing, income data from follow-up exams were used. A continuous measure of household-equivalized income was created by taking the midpoint for each income category and dividing it by the number of household members. The variable was expressed as quartiles of the sample distribution. Time since baseline (years) was used to examine change in BMI and WC over time.

We also tested whether lifestyle behaviors mediated associations between BMI and WC with nativity and length of US residence. Current cigarette smoking status (yes/no/former) and current alcohol consumption (yes/no) were ascertained at all visits. Physical activity, available at the first three exams, was measured as metabolic equivalent task-minutes per week for walking and moderate- and vigorous-intensity sports and conditioning activities, estimated from a physical activity questionnaire adapted from the Cross-Cultural Activity Participation Study (26). Diet was measured at baseline using an adapted 120-item food frequency questionnaire, validated for multiethnic populations (27). We operationalized diet in two ways: total caloric intake (kcal) and a dietary pattern score that characterizes intake of fats and processed foods. The latter was identified through a factor analysis of diet patterns among 47 food groups (28). Higher scores indicate higher intake of fats and processed foods.

Of the 2,299 Hispanic and Chinese participants, 11 did not have information on key covariates, yielding a sample of 1,486 Hispanics (794 Mexican, 692 non-Mexican) and 802 Chinese. Of the non-Mexican Hispanics, 29% were Puerto Rican, 25% were Dominican, 8% were Cuban, and the remaining were from several Central and South American countries. Mediation analyses using diet were restricted to 1,350 Hispanics and 790 Chinese because of missing diet data. Of the 2,288 baseline sample, 77% had information for all four visits, 13% had information for two or three visits, and 7% had only baseline information. Analyses included all 2,288 baseline participants regardless of missing follow-up information. All MESA participants provided written informed consent.

Statistical analysis

Results were race/ethnicity-stratified (Hispanics and Chinese). We used graphical methods to explore relationships of BMI and WC with age and time since baseline in order to evaluate departures from linearity. BMI had a curvi-linear relationship with age; thus, we included a quadratic age term in all BMI models. We estimated cross-sectional and longitudinal associations between nativity and BMI and WC, separately, using a repeated measures analysis with the unstructured covariance specification to account for within-person correlations (29) (PROC MIXED SAS 9.2; SAS Institute Inc., Cary, NC). Models were adjusted for baseline age, sex, site, education, income, and time since baseline. Baseline age-by-time interactions were retained to account for the significantly greater BMI and WC increases among participants younger at baseline. We also included time interactions with education and income to adjust for differential trends by socioeconomic status (SES). To evaluate whether BMI and WC change varied by nativity, we tested nativity-by-time interactions.

We also examined whether differences in physical activity, smoking, alcohol, and diet potentially mediated the relationship between nativity and BMI or WC by including these measures as time-varying covariates when available. Because diet was only ascertained at baseline, we modeled its interaction with time in lieu of a time-varying covariate. To examine heterogeneity in the associations of nativity with BMI and WC by Hispanic subgroup, we included a covariate for Mexican-origin status in Hispanic models. Mexican-origin status was interacted with nativity and with time. We also included a three-way interaction between Mexican-origin, nativity, and time to determine whether Mexican origin modified the impact of nativity on time trends. We computed estimates of adjusted mean annual change in BMI and WC by nativity and by Mexican origin using model coefficients.

To examine whether change in BMI or WC differed by time lived in the US at baseline, we also fit models that replaced the nativity indicator with a 5-level variable that combined birthplace and baseline length of US residence among the FB (FB: <15 years; FB: 15-30 years; FB: >30 years; FB: missing years in US; and US-born [referent]). We tested an interaction between this 5-level variable and time in ethnicity-stratified models.

Because 23% of our sample did not have complete information on all study visits, we re-ran all models on individuals with complete data for all four visits. Change-over-time estimates from our complete-case analysis were robust regardless of follow-up length, suggesting that BMI and WC trajectories among individuals lost to follow-up did not differ from those remaining in the study.

Results

FB Hispanic and Chinese participants had lower baseline BMI and WC than their US-born (USB) counterparts (mean WC for FB and USB: 99 vs. 103 cm, $P < 0.0001$ for Hispanics; and 87 vs. 92 cm, $P = 0.09$ for Chinese). The proportion of individuals who were obese or abdominally obese was also lower in the FB (Table 1). The FB also had greater 5-year mean increase in BMI and WC though differences were not statistically significant (5-year increase in WC in FB vs. USB: 1.75 vs. 1.08 cm, $P = 0.09$ in Hispanics; 1.21 vs. 0.26 cm, $P = 0.40$ in Chinese). FB participants were disproportionately represented in the lowest socioeconomic categories, and had lower physical activity levels, but more favorable profiles for diet, smoking, and alcohol consumption compared with the US-born. Nativity differences among Hispanics were similar regardless of ethnicity with some exceptions. First, the nativity difference in baseline BMI and WC was smaller among Mexican Hispanics. Second, the proportion of women with abdominal obesity was higher among FB Mexicans compared with that among US-born; this pattern was reversed among non-Mexican Hispanics. Finally, SES disparities by nativity were considerably wider for Mexican than for non-Mexican Hispanics.

Multivariable analyses

Table 2 shows adjusted mean differences in baseline BMI and WC and in annual changes in BMI and WC by nativity for Hispanics and Chinese. Adjusting for age, sex, site, education, income, and time (Model 1), the FB had a significantly lower mean baseline BMI and WC than the US-born (Hispanics (BMI): mean difference = -1.55 kg/m^2 , $P < 0.0001$; (WC): -3.66 cm , $P < 0.0001$; Chinese (BMI): -1.68 kg/m^2 , $P < 0.01$; (WC): -5.13 cm ,

$P < 0.01$). Mean annual changes in BMI were not statistically significant and there were no differences by nativity status in change over time. All groups except US-born Chinese experienced statistically significant annual increases in WC, but there were no significant differences by nativity status for either ethnic group. Inclusion of time-varying measures of physical activity, smoking, and alcohol (Model 2) slightly increased nativity differences at baseline. Further, addition of baseline dietary measures (Model 3) partially reduced nativity differences in baseline BMI and WC for Hispanics and in baseline WC for Chinese.

Tests for interactions revealed significant heterogeneity by Mexican-origin among Hispanics (Likelihood ratio test: BMI model: $P = 0.0087$; WC model: $P = 0.0020$). The patterns were generally similar in both BMI and WC models, but associations were more pronounced in WC models, so only those results are shown (Table 3) (see Supporting Information Table S1 for results for BMI models). Mexican Hispanics had significantly smaller nativity differences in baseline WC (mean difference = -2.19 , $P < 0.05$) compared with non-Mexican Hispanics (mean difference = -7.88 , $P < 0.0001$) (Model 1). Although all four Mexican-origin/nativity combinations experienced increases in WC over time, the Mexican FB had greater increases over time compared to both the Mexican US-born (difference in mean annual change = 0.28 , $P < 0.05$) and the non-Mexican FB (difference in mean annual change = 0.24 , $P < 0.01$) (Model 1). In contrast, we found no significant difference by nativity in mean change over time among non-Mexican Hispanics. There were also no differences in mean change over time between Mexican and non-Mexican US-born individuals. Inclusion of health behaviors did not meaningfully alter estimates (Model 2). Results were robust to adjustment for length of US residence among the FB.

Figure 1A-C presents 5-year trends in adjusted mean WC by baseline length of US residence. Because BMI changed little over time, we only graphed the findings from WC models. Among Mexican Hispanics, only the most recent immigrants (<15 years) had a significantly lower baseline mean WC than the US-born (Figure 1A) (mean difference = -3.77 cm , $P = 0.0470$). However, rates of increase over time for this group were significantly greater than for the US-born (mean difference in annual change = 0.48 cm , $P < 0.0236$); after 5 years, WC estimates for recent immigrants no longer statistically differed from the US-born. Although the other Mexican immigrant groups did not differ from the US-born in baseline WC, they also had a significantly greater rate of increase than the US-born. Results were robust to stratification by baseline age.

Among non-Mexican Hispanics (Figure 1B) and Chinese (Figure 1C), the baseline WC of the FB was significantly lower relative to the US-born, regardless of length of residence, but there were no differences in WC change over time.

Discussion

We examined differences in BMI and WC and in their change over time by nativity and ethnicity in a prospective multiethnic cohort. Foreign birth was associated with a lower adjusted mean baseline BMI and WC among both Hispanics and Chinese, but there were no significant time trend differences by nativity. However among Hispanics, there was significant heterogeneity by subgroup. Baseline nativity differences in WC for Mexican Hispanics were narrower than

TABLE 1 Sample characteristics by nativity and ethnicity, the Multi-ethnic Study of Atherosclerosis

	All Hispanics		Mexican Hispanics		Non-Mexican Hispanics		Chinese	
	Birth country		Birth country		Birth country		Birth country	
	U.S.	Other	U.S.	Other	U.S.	Other	U.S.	Other
	(n = 465)	(n = 1021)	(n = 403)	(n = 391)	(n = 62)	(n = 630)	(n = 30)	(n = 772)
Mean BMI (kg/m²) (SD) [n]								
Baseline	30.5 (5.7) [465]	28.9 (4.7)* [1021]	30.4 (5.6) [403]	29.4 (4.8)* [391]	31.0 (6.3) [62]	28.6 (4.7)* [630]	25.7 (5.0) [30]	23.9 (3.2) [772]
First follow-up	30.6 (5.9) [434]	29.1 (4.9)* [914]	30.4 (5.8) [376]	29.7 (4.9) [337]	31.3 (6.7) [58]	28.7 (4.9)* [577]	25.8 (5.0) [30]	24.0 (3.2)* [697]
Second follow-up	30.6 (5.9) [415]	29.1 (4.9)* [839]	30.5 (5.8) [359]	29.9 (4.9) [298]	31.3 (6.3) [56]	28.7 (4.9)* [541]	25.8 (4.9) [29]	23.9 (3.3)* [667]
Third follow-up	30.6 (6.0) [408]	29.2 (5.1)* [812]	30.5 (5.9) [353]	30.2 (5.2) [288]	31.5 (6.7) [55]	28.7 (4.9)* [524]	25.6 (4.6) [28]	24.0 (3.4) [630]
Mean 5-year change in BMI (SD)	-0.012 (2.3)	0.16 (2.1)	0.002 (2.1)	0.38 (2.1)*	-0.11 (2.9)	0.03 (2.0)	0.006 (1.5)	0.02 (1.4)
Obese^a baseline (%)	46.9	34.9*	46.7	39.9	48.4	31.8*	16.7	4.0*
Mean waist circumference (cm) (SD) [n]								
Baseline	103.2 (14.5) [465]	99.4 (12.2)* [1021]	102.8 (14.4) [403]	100.9 (11.5)* [391]	105.6 (15.1) [62]	98.5 (12.6)* [630]	91.8 (15.4) [30]	86.9 (9.6) [772]
First follow-up	103.1 (15.2) [434]	99.7 (12.4)* [914]	102.7 (15.1) [376]	101.3 (11.6) [337]	105.4 (15.7) [58]	98.7 (12.8)* [577]	91.5 (15.6) [30]	86.7 (9.5) [697]
Second follow-up	104.1 (14.9) [415]	100.2 (12.5)* [839]	103.6 (14.8) [359]	102.9 (11.8) [298]	107.7 (15.1) [56]	98.7 (12.6)* [541]	91.2 (16.0) [29]	87.1 (9.6) [667]
Third follow-up	104.4 (15.1) [408]	101.1 (12.9)* [812]	104.0 (14.9) [353]	103.8 (12.2) [288]	107.5 (16.1) [55]	99.7 (13.1)* [524]	91.5 (13.9) [28]	88.1 (9.6) [630]
Mean 5-year change in waist circumference (SD)	1.08 (6.7)	1.75 (6.4)	1.23 (6.5)	2.23 (6.4)*	0.1 (7.5)	1.48 (6.5)	0.26 (0.57)	1.21 (5.2)
Abdominal obesity, baseline (%)	48.4	37*	48.8	37.4*	45.2	36.7	17.6	7
Men: ≥ 102 cm ^b	82.2	80.3	80.8	88.7*	90.3	75.3*	53.8	40.8
Women: ≥ 88 cm ^b								
Study site (%)								
Forsyth County, NC	0.4	0.1*	0	0	3.2	0.16*	0	0
New York, NY	8.4	44.8	0.5	0.51*	59.7	72.2	0	0.26*
Minneapolis, MN	52.7	20.7	58.6	36.1	14.5	11.1	0	0
Chicago, IL	0	0	0	0	0	0	66.7	36.7
Los Angeles, CA	38.5	34.5	40.9	63.4	22.6	16.5	33.3	63.1
Mean age, baseline (SD)	61.6 (10.5)	61.1 (10.2)	62.0 (10.3)	60.8 (10.2)	58.8 (11.3)	61.2 (10.3)	61.1 (10.0)	62.4 (10.3)
Female (%)	47.1	53.7*	46.6	52.2	50	54.6	43.3	51.8
Mexican origin (%)	86.7	38.3*						
Years lived in U.S., baseline (among foreign-born) (%)								
<15 years		15.6		21		12.2		36.3
15-30 years		24.6		25.3		24.1		38.3
>30 years		48.4		41.9		52.4		18.6
Missing		11.5		11.8		11.3		6.7

TABLE 1 (Continued)

	All Hispanics		Mexican Hispanics		Non-Mexican Hispanics		Chinese	
	Birth country		Birth country		Birth country		Birth country	
	U.S. (n = 465)	Other (n = 1021)	U.S. (n = 403)	Other (n = 391)	U.S. (n = 62)	Other (n = 630)	U.S. (n = 30)	Other (n = 772)
Education (%)								
Less than high school	20	55.7*	21.3	73.7*	11.3	44.6	3.3	25.6*
Completed high school/GED	28.2	16.8	28.3	10.5	27.4	20.8*	20	16.1
Some college/technical school	39.3	18.6	38.2	13.5	46.8	21.7	13.3	20.3
Bachelor's/graduate degree	12.5	8.8	12.2	2.3	14.5	12.9	63.3	38
Income quartiles, U.S.\$^c (%)								
0	12	35.3*	12.2	47.8*	11.3	27.5*	3.3	29.8*
1	13.3	23.5	13.1	25.3	14.5	22.4	3.3	23.5
2	34	24.4	34.7	18.2	29	28.2	26.7	20.3
3	40.6	16.8	40	8.7	45.2	21.9	66.7	26.4
Diet of high fats, processed foods, mean score (SD)^d	0.05 (0.94)	-0.48 (0.80)*	0.0144 (0.93)	-0.57 (0.72)*	0.31 (1.02)	-0.42 (0.84)*	-0.06 (0.79)	-0.69 (0.46)*
Mean caloric intake, kilocalories (SD)^d	1812 (1014)	1779 (890)	1790 (1023)	2027 (883)*	1973 (947)	1608 (855)*	1710 (762)	1320 (572)*
Total intentional exercise, baseline (MET-min/week) (%)								
0	23.4	34.5*	23.8	41.9*	21	29.9	10	25.9*
<2400	49	51.9	48.4	51.4	53.2	52.1	60	60.9
≥2400	27.5	13.6	27.8	6.7	25.8	18	30	13.2
Smoking status, baseline (%)								
Never	46.4	57.4*	47.2	57*	41.9	57.6*	43.3	76.5*
Former	38.9	29.6	38.7	32.2	40.3	27.9	50	17.9
Current	14.6	13	14.1	10.8	17.7	14.4	6.7	5.6
Current alcohol drinker, baseline (%)								
Yes	55.3	43.6*	54.8	39.6*	58.1	46.1	56.7	30.3*
No	44.7	56.4	45.2	60.4	41.9	53.9	43.3	69.7

MET, metabolic equivalent task; SD, standard deviation.

^aBMI ≥ 30 kg/m².

^bBased on the World Health Organization's sex-specific cutoffs for waist circumference measurements at high risk for metabolic syndrome.

^cContinuous measure of income adjusted for household size, expressed as quartiles.

^dBased on restricted sample of 1350 Hispanics (424 U.S.-born (U.S.B), 926 foreign-born (FB)); 749 Mexican (372 U.S.B, 377 FB); 601 non-Mexican Hispanics (52 U.S.B, 549 FB); and 790 Chinese (28 U.S.B, 762 FB).

*p < 0.05, comparing foreign-born to U.S.-born within ethnic groups.

TABLE 2 Adjusted mean difference at baseline and mean annual change in BMI (kg/m²) and waist circumference (WC) (cm) by nativity, Hispanics and Chinese

	Model 1		Model 2		Model 3	
	BMI	WC	BMI	WC	BMI	WC
HISPANICS (n = 1486)						
Mean difference in baseline BMI and WC						
US born	Ref	Ref	Ref	Ref	Ref	Ref
Foreign-born	-1.55 (0.34)*	-3.66 (0.87)*	-1.58 (0.34)*	-3.76 (0.87)*	-1.44 (0.36)*	-3.42 (0.93)**
Mean annual change in BMI and WC by nativity^a						
US born	0.03 (0.03)	0.28 (0.11)***	0.03 (0.04)	0.25 (0.11)****	0.04 (0.04)	0.28 (0.11)****
Foreign-born	0.04 (0.02)	0.39 (0.07)*	0.04 (0.02)	0.39 (0.08)*	0.05 (0.03)	0.38 (0.08)*
Mean difference in annual change in BMI and WC						
US born	Ref	Ref	Ref	Ref	Ref	Ref
Foreign-born	0.01 (0.03)	0.11 (0.08)	0.01 (0.03)	0.14 (0.08)	0.01 (0.03)	0.11 (0.09)
CHINESE (n = 802)						
Mean difference in baseline BMI and WC						
US born	Ref	Ref	Ref	Ref	Ref	Ref
Foreign-born	-1.68 (0.62)***	-5.13 (1.83)***	-1.70 (0.62)***	-5.23 (1.84)***	-1.72 (0.66)***	-4.78 (1.95)****
Mean annual change in BMI and WC by nativity^a						
US born	0.07 (0.06)	0.24 (0.23)	0.07 (0.06)	0.24 (0.23)	0.05 (0.06)	0.16 (0.24)
Foreign-born	0.04 (0.03)	0.37 (0.10)**	0.04 (0.03)	0.36 (0.10)**	0.03 (0.03)	0.33 (0.11)***
Mean difference in annual change in BMI and WC						
US born	Ref	Ref	Ref	Ref	Ref	Ref
Foreign-born	-0.03 (0.06)	0.13 (0.21)	-0.03 (0.06)	0.12 (0.21)	-0.02 (0.06)	0.17 (0.22)

Estimates shown were calculated to correspond to the mean age of the entire sample (age=63) and to those with less than high school education and in the lowest income quartile.

Model 1 adjusted for age, sex, site, baseline education and income, time since baseline, and interactions for age*time, education*time, and income*time. BMI model includes age² term.

Model 2 adds controls for time-varying health behaviors: physical activity, current smoking status, current alcohol use.

Model 3 adds baseline dietary measures (diet of high fats, processed foods; total caloric intake); restricted to 1,350 Hispanics and 790 Chinese on whom dietary data were available. Sensitivity analyses confirmed that results from previous models excluding missing dietary data did not appreciably affect results.

*P < 0.0001, **P < 0.001, ***P < 0.01, ****P < 0.05.

they were for non-Mexican Hispanics. FB Mexicans also experienced greater annual mean increases in WC than both US-born Mexican and FB non-Mexican Hispanics, regardless of how long they had lived in the United States.

Consistent with our baseline results, prior cross-sectional work has documented lower weight in the FB than the US-born among Hispanics (3,5,6,8,16,30,31), Mexican-Americans (32-36), Asians (2,4,6,30,31,36), and Chinese-Americans (36), though null findings among Asians have also been reported (5). Studies examining cross-sectional associations between length of residence and weight show evidence of higher BMI, WC, or obesity with longer US residence in nationally representative studies of Hispanics (2,3,8-10), as well as in region-specific studies (5,6), and studies specific to Mexican and Puerto Rican subgroups (7,32). Results among Asians (2,4-6) and Chinese (36,37) are mixed. To our knowledge, no longitudinal studies have directly examined the relation between time in the United States and changes in weight over time among adults.

A major limitation in drawing inferences regarding the causal effect of length of residence on weight from cross-sectional analyses is the

inability to differentiate the influence of time in the US from cohort and aging effects. Controlling for age and its interaction with time in a longitudinal design, we were able to directly examine whether the FB experienced greater increases in BMI or WC with longer length of residence relative to the US-born, net of age, and birth cohort. Contrary to much of the cross-sectional literature that did not account for these influences, we did not find evidence of greater BMI and WC increases over time among FB Hispanics and Chinese. However, our results were consistent with one cross-sectional study of Hispanics that did account for age and cohort influences. Park et al utilized a series of repeated cross sections to evaluate changes in the obesity prevalence of foreign and US-born age-matched cohorts over a period of 10 years. They found no evidence that immigrant obesity converged to US-born levels (16). In another longitudinal analysis conducted in a sample of multiethnic adolescents (whites, blacks, Hispanics, and Asians), first-generation immigrants experienced slower increases in BMI than second- and third-generation adolescents (38). Of relevance, these patterns remained consistent for Hispanics and Asians. Taken together, these two studies support our findings in older Hispanic and Chinese adults in which we find no evidence of faster increases in BMI or WC in the FB compared to the US-born after accounting for aging and cohort influences.

TABLE 3 Adjusted mean waist circumference (WC) (cm) at baseline and mean annual change in WC by nativity and Mexican ethnicity

	Model 1			Model 2 ^a		
	Adjusted mean baseline WC (SE) ^b		Mean difference in baseline WC by nativity (SE) ^c	Adjusted mean baseline WC (SE) ^b		Mean difference in baseline WC by nativity (SE) ^c
	U.S.-born	Foreign-born		U.S.-born	Foreign-born	
Mexican Hispanics (n = 794)	103.40 (1.18)	101.21 (0.89)	-2.19 (1.04)****	103.66 (1.21)	101.32 (0.95)	-2.34 (1.10)****
Non-Mexican Hispanics (n = 692)	107.34 (1.98)	99.47 (1.15)	-7.88 (1.75)*	107.67 (2.10)	100.22 (1.17)	-7.45 (1.89)*
Mean difference in baseline WC by Mexican ethnicity for each nativity group (SE) ^d	-3.94 (1.89)****	1.74 (1.14)		-4.01 (1.99)****	1.10 (1.15)	

	Adjusted mean annual change (SE) ^b		Mean difference in annual change in WC by nativity (SE) ^c	Adjusted mean annual change (SE) ^b		Mean difference in annual change in WC by nativity (SE) ^c
	U.S.-born	Foreign-born		U.S.-born	Foreign-born	
	Mexican Hispanics	0.23 (0.11)****	0.51 (0.09)*	0.28 (0.11)****	0.23 (0.12)****	0.52 (0.10)*
Non-Mexican Hispanics	0.13 (0.19)	0.26 (0.09)**	0.13 (0.18)	0.08 (0.21)	0.26 (0.09)***	0.17 (0.20)
Mean difference in annual change in WC by Mexican ethnicity for each nativity group (SE) ^d	0.10 (0.18)	0.24 (0.09)***		0.15 (0.20)	0.26 (0.10)***	

Model 1 adjusted for age, sex, site, baseline education and income, Mexican-origin status, time since baseline, and interactions for age × time, education × time, income × time, Mexican-origin × time, Mexican-origin × nativity, and Mexican-origin × nativity × time. Model 2 adds controls for time-varying health behaviors: physical activity, current smoking status, current alcohol use, and baseline dietary measures (diet of high fats, processed foods; total caloric intake).

^aModel 2 restricted to 749 Mexicans and 601 non-Mexican Hispanics on whom dietary data was available. Sensitivity analyses confirmed that results from previous model excluding missing dietary data did not appreciably affect results

^bAdjusted mean estimates shown are calculated to correspond to the mean age of the entire sample (age=63) and to those with less than high school education and in the lowest income quartile.

^cCompares foreign-born to US-born referent for each Mexican-origin group.

^dCompares Mexican to non-Mexican referent for each nativity group.

Likelihood ratio test comparing nested models with and without interaction terms for Mexican ethnicity: $P = 0.0082$.

* $P < 0.0001$, ** $P < 0.001$, *** $P < 0.01$, **** $P < 0.05$.

A strength of our analysis was the ability to examine whether patterns differed in Hispanic subgroups. Failure to distinguish by subgroup can mask heterogeneity among Hispanics. Although analyses pooling Hispanics showed no evidence that the FB experienced a more rapid increase in BMI or WC than the US-born, FB Hispanics of Mexican origin experienced more rapid increases than US-born Mexican-Americans. They also experienced more rapid increases than other FB Hispanics. Reasons underlying the findings among FB Mexicans remain unclear. Adoption of negative health behaviors has been hypothesized to account for the increased weight associated with longer length of US residence (11); however, inclusion of behavioral covariates in models did not fully account for our findings. Measurement error may have resulted in underestimates of their importance as mediators; missing dietary data and the availability of baseline-only measurements likely limited our ability to quantify the relevance of diet. Similarly, we used leisure-time activity to measure energy expenditure, which does not capture activity associated with occupation, or with activity not considered “leisure-time” by respondents.

There are other factors that could explain why trajectories over time in anthropometric characteristics among the FB differed depending on

their ethnic origin. These factors may include exposure to different cultural environments, variation in opportunity for socioeconomic advancement, and influence of characteristics associated with a migrant’s country of origin (11). Health behaviors established in the sending country likely remain important influences after migration. Among immigrants from Mexico, a country where the obesity epidemic rivals that of the United States (39), poorer health behaviors established prior to migration may contribute to more adverse weight patterning among Mexican origin individuals compared with immigrants from other parts of Latin America where obesity has not yet reached epidemic levels.

The receiving environments may also differ across various groups of immigrants. Migration to and residence in environments marked by poverty, crime, and deficiency in physical and social resources may reinforce poorer health behaviors, and contribute to adverse changes in anthropometric indicators (40). There is also some work to suggest that residence in immigrant enclaves may facilitate retention of traditional, healthier diets through greater availability of fruits and vegetables and other ethnic-specific food options (41,42). Better access to health-promoting resources in the receiving environment may be one mechanism through which some immigrants may be

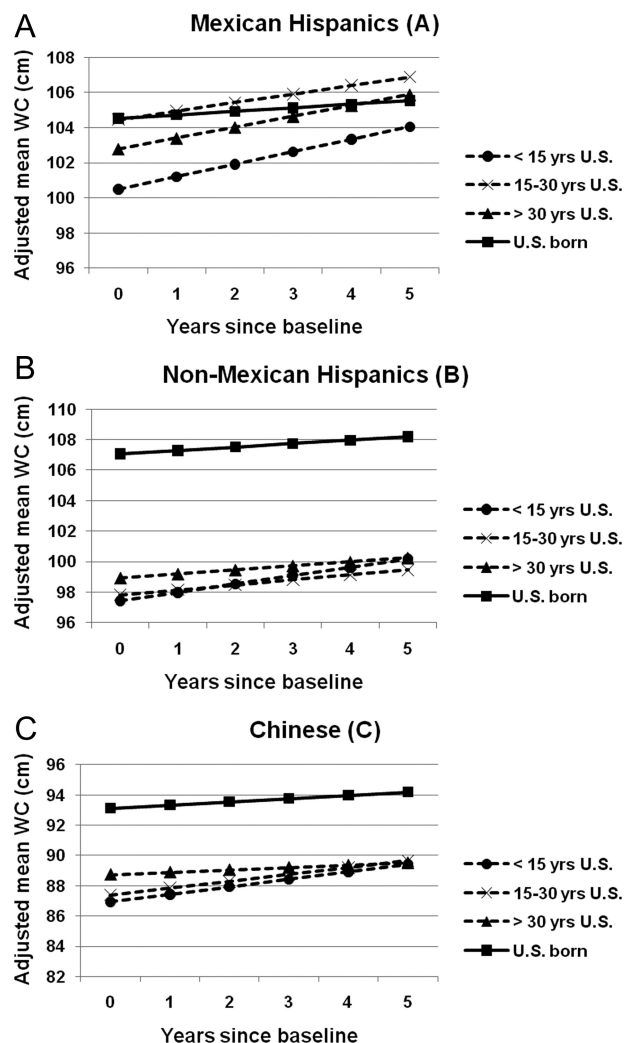


FIGURE 1 Adjusted mean waist circumference trajectories over time by baseline length of US residence among the foreign-born and the US born. (A) Mexican Hispanics, (B) non-Mexican Hispanics, (C) Chinese. WC, waist circumference; Yrs, years. All models adjusted for age, sex, site, education, income, baseline length of US residence \times time, and health behaviors (physical activity, smoking, alcohol, and diet). Estimates shown were calculated to correspond to the mean age of the entire sample (age = 63) and to those with less than high school education and in the lowest income quartile. Foreign-born with missing data on baseline length of US residence included in all models but not plotted in figures.

buffered against the health declines commonly associated with longer time in the United States. Although it is unclear if access to such resources was differentially distributed between FB Mexicans and non-Mexican Hispanics, for example, future exploration of the impact of contextual features could provide additional insight into the factors that facilitate, or buffer against, weight gain across immigrant groups.

Methodological explanations may also underlie findings among FB Mexicans. Despite the robustness of our complete-case analysis, if loss to follow-up among the FB was correlated with a lower propensity to gain weight, this would bias findings in the direction we observed. We also elected against adjustment for baseline BMI and

WC in multivariable models. The extent to which baseline values should be controlled for in models estimating change over time is debatable, especially when the variables of interest are associated with the baseline measurements, and when there is error in the baseline measurement (43). However, because the most notable change-estimate differences were between groups with smaller differences in baseline measurements, we believe baseline differences are an unlikely explanation for our main findings.

Our study had some limitations. Sample size precluded investigation of heterogeneity among non-Mexican Hispanics. The small number of US-born Chinese may have also hampered our ability to detect nativity differences. Future studies with larger samples of US-born Chinese and Hispanic subgroups are warranted to confirm our findings. Sample size limitations also made it difficult for us to investigate whether the complex patterns we report differed across socioeconomic groups. Additional work is needed to further clarify the interplay of migration, ethnicity, and socioeconomic position in shaping health trajectories after migration. The older age of the cohort and relatively short follow-up may have also limited our ability to examine factors associated with changes over time. Trajectories of weight gain may be established much earlier in life, and factors proxied by the nativity variables we utilized may have limited impact at older ages. Finally, because MESA is a relatively older, healthy cohort sampled from selected sites, the generalizability of these findings to other US immigrant groups may be limited.

To our knowledge, this is among the first studies to examine trajectories of BMI and WC among immigrants in a longitudinal multiethnic cohort of adults. We found ethnic heterogeneity in BMI and WC change over time with Mexican immigrants exhibiting greater increases relative to both US-born Mexican Hispanics and FB non-Mexican Hispanics. High WC has consequences for progression to CVD and metabolic abnormalities (25). Since Mexican Hispanics constitute the largest immigrant group and Hispanic subgroup in the United States, if confirmed in larger national samples, the findings we report will have implications for future disease burden and mortality in the United States. The ethnic heterogeneity we observed suggests that the acculturation process and its associated health consequences may not be homogeneous for all immigrants. It is important to develop a better understanding of the multiplicity of factors that may buffer some groups against more adverse health outcomes while placing others at higher risk of health decline with more time in the United States. Further insight into what may underlie these patterns would facilitate development of interventions to prevent the health deterioration that appears with longer US residence in some immigrant groups. Moreover, understanding what factors may buffer some immigrant groups against deleterious health consequences of more time in the US may help uncover targets for intervention that may benefit other immigrant groups in the future. **O**

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