Heterogeneity in the Association between Acculturation and Adiposity among Immigrants to the United States

by

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Dedication

To my parents: for their encouragement and support in pursuing higher education despite a background of limited education. Also to my extended family from Ecuador, both back in the home country, and now living in Queens, NY - for providing the inspiration and motivation for this work.

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Abstract

U.S. birth and longer length of U.S. residence among immigrants have been associated with a higher risk of obesity. However, few studies have examined this pattern longitudinally or examined heterogeneity in this relationship. Doing so may inform how social processes that relate to different immigrant integration patterns impact obesity. Using prospective data from the Multi-Ethnic Study of Atherosclerosis (MESA) and repeated, cross-sections from the National Health and Nutrition Examination Survey (NHANES), this dissertation examined: 1) differences in rates of waist circumference (WC) increase among U.S. and foreign-born Hispanic and Chinese adults (MESA); 2) the role of the neighborhood environment in moderating the relationship between nativity/length of U.S. residence and WC among Hispanic and Chinese adults (MESA); and 3) variation over time in the relationship between nativity/length of U.S. residence and body mass index (BMI) and WC among Mexican-American adults (NHANES). Results demonstrated that longer exposure to the U.S. context does not have the same implications for weight gain for all immigrants. In MESA, Hispanic and Chinese immigrants did not have a greater rate of increase in WC over time relative to the U.S.-born; however, foreign-born Mexican Hispanics experienced an accelerated rise in WC compared to both U.S.-born Mexican Hispanics and foreign-born non-Mexican Hispanics. Hispanic immigrants living in neighborhoods with greater healthy food

availability had a lower mean WC than immigrants in neighborhoods with poor healthy food availability. Among Chinese, more recent immigrants living in more walkable neighborhoods increased in WC more slowly than recent immigrants in less walkable areas. Among Mexican-Americans in NHANES, there was a graded relationship between longer length of U.S. residence and higher BMI and WC, and this relationship did not change substantially between 1988-1994 and 2005-2008. However, there were important variations in this patterning by gender and by socioeconomic status. The share of immigrants in the U.S. population continues to grow. A more nuanced understanding of the impact of the U.S context on the health of this vulnerable group will inform public health interventions, and address troubling health disparities.

Chapter 1

Introduction

Over the past 20 years, immigrants have represented a growing share of the U.S. population. A central theme to emerge from studies of immigrants to the U.S. is the documentation of a health advantage among immigrants over the native-born. As immigrants acculturate to American society, this apparent health advantage appears to diminish, possibly through the adoption of unhealthy behaviors prevalent in the host culture.

Obesity is a major risk factor for cardiovascular disease (CVD) affecting an increasingly large segment of the U.S. population. Many studies that have examined the relationship between acculturation and body mass index (BMI) have reported a lower risk of obesity among the foreign-born compared to the U.S.-born. Longer time in the U.S. has been associated with weight levels among the foreign-born that appear to converge to levels among the U.S.-born.

However few studies have investigated this relationship in a longitudinal manner and few have accounted for heterogeneity. Cross-sectional analyses of acculturation and measures of weight may conflate differences between individuals in different cohorts with the effects of time on a single individual, and may obscure any temporal trends in the relationship. The health consequences of acculturation may also be modified by

various factors including ethnicity, the residential environments, and calendar time. Ethnicity may be a function of cultural and behavioral practices associated with the country of origin and of features of the receiving environments in which specific immigrant ethnic groups settle. The area of residence itself also has implications for dietary and activity patterns that may contribute to the associations between acculturation and weight. Areas with limited resources for physical activity and healthy eating, for example, are thought create an environment that fosters poor health behaviors that may lead to higher obesity. However, the role of these environmental features in explaining or moderating the effects of acculturation on weight has not been thoroughly investigated. Finally, there may be secular variation in the relationship between measures of acculturation and weight. In light of increasing trends in global obesity, more recent waves of immigrants may be arriving with higher weight measures than earlier cohorts. Although longer length of U.S. residence may have been associated with higher obesity at a certain point in time, it is unclear if this relationship continues to hold for later waves of immigrants, many of whom are arriving from countries marked by their own obesity epidemics.

To address some of the limitations in the literature, this dissertation used longitudinal data in 2 of the 3 aims, and examined heterogeneity in the association between acculturation and measures of anthropometry in 3 ways: 1) by ethnicity, 2) by the residential neighborhood environment, and 3) by calendar time. Doing so may inform how social processes that relate to different immigrant integration patterns impact obesity. Uncovering sources of heterogeneity also points to immigrant groups that may

benefit most from interventions efforts. As the share of immigrants in the U.S. population grows, a better understanding of the anthropometric patterns in this population will be important for estimating future trends in obesity prevalence and associated health burden and costs. Further insight into the relationship between exposure to the U.S. environment and adiposity would also inform the design of interventions to preserve health and forestall the deterioration that may appear with longer time in the U.S.

Specific Aims and Hypotheses

Aim 1: To examine whether foreign-born Hispanic and Chinese adults experience greater increases in waist circumference (WC) over time relative to their U.S.-born counterparts, and to investigate heterogeneity in this relationship by Hispanic subgroup.

Hypothesis 1a: The rate of WC increase over time will be greater among the foreign-born than the U.S.-born, consistent with the concept of convergence of foreign-born weight to U.S.-born levels.

Hypothesis 1b: Among Hispanics, Mexican-origin Hispanics will have a faster rate of WC increase than their U.S.-born counterpart compared to non-Mexican Hispanics.

Aim 2: To investigate whether neighborhoods of residence play a role in moderating the relationship between nativity/length of U.S. residence and waist circumference (cross-sectionally and longitudinally) among Hispanics and Chinese adults.

Hypothesis 2a: The cross-sectional association between nativity/length of U.S. residence and waist circumference will be smaller in neighborhood environments with poorer healthy food availability and walkability.

Hypothesis 2b: Over time, the waist circumference of the foreign-born will converge more rapidly to U.S.-born levels in neighborhoods with poorer healthy food availability and walkability.

Aim 3: To examine whether the relationship between nativity/length of U.S. residence and body mass index and waist circumference varies by calendar time in a nationally representative sample of Mexican-American adults.

Hypothesis 3: The association between higher acculturation and higher BMI and waist circumference will be stronger in earlier calendar years (1988-1994) compared to more recent calendar years (2005-2008).

Immigrants and Health

In light of the rising tide of immigration over the past two decades, a number of studies have begun to explore health patterns among the foreign-born, particularly among Latinos and Asians, two groups that constitute the majority of the contemporary immigrant population. A central theme that has emerged is the observation of a 'healthy immigrant effect' whereby new immigrants appear to have a health advantage over those native-born (1). A complementary theme has also been recognized, often referred to as the 'acculturation hypothesis,' which posits a loss in this apparent advantage for

immigrants with increasing time spent living in the U.S. The suggestion is that any protective cultural buffering offered by immigrant status may diminish with increasing acculturation, resulting in a variety of health outcomes that approach levels found in the general U.S. population (2).

Potential explanations that have been offered for this initial health advantage have focused on selective migration and protective cultural factors (3). Individuals that choose to and are able to migrate are thought to be younger and healthier relative to their native populations, and are thus selected for their ability to better cope with the rigors of the migration process. In addition, host countries with medical screening processes have also historically been more inclined to allow entry to migrants in good health resulting in immigrant streams that may not actually necessarily be representative of their native counterparts with respect to a number of health indicators. There is some evidence of health selection among immigrants however validly quantifying this process has been difficult, and support for it remains mixed (3, 4). Cultural factors have also been cited as part of the rationale for the apparent initial health advantage. It has been hypothesized that values and customs rooted in an immigrant's native society may serve to foster better health behaviors, possibly through the presence of stronger family ties and other forms of social support (3).

To explain the later decline associated with increasing exposure or time in the U.S., hypotheses have concentrated on processes related to stress, and the interplay of social, economic, cultural, and environmental influences, resulting in the convergence of health to host country levels. Stresses associated with the migration process, including

disruption of supportive networks that may have existed in an immigrant's native country, and the adjustment to a new and sometimes hostile environment may be a pathway through which migration and re-settlement may adversely affect health (5). Particularly in the case of ethnic minorities, some investigators have also suggested that 'othering' processes and discrimination could also facilitate adoption of more negative health behaviors through limitations on access to resources (6).

More generally studied is the concept of acculturation, defined as a process whereby immigrants over time come to adopt the behaviors and norms of their new culture. This deterioration in health that has been linked to the process of acculturation is thought to be related not only to acquisition of negative risk factors, such as poorer diet and increases in smoking and alcohol intake, but may also involve the loss of protective factors after leaving country of origin (7). With respect to weight gain, in qualitative studies, lack of personal time, increased social isolation, and physical environments characterized by limited availability of healthy foods and other resources have also been implicated in contributing to the later decline of health (2). Some evidence however also suggests a link between acculturation and more positive outcomes with respect to education, income and upward mobility, as well as to health indicators related to physical activity and access to care (8, 9).

Acculturation

In most health studies of immigrants, acculturation has been construed in more simplistic terms despite recognition of the great complexity surrounding the construct. Considerable debate continues with respect to its conceptualization, measurement, and

even utility, and no standardized methods have been created to validly capture this multi-dimensional process (9-11). Traditionally, health studies of acculturation have viewed the process more through the lens of classical assimilation theory whereby immigrants over time come to adopt the habits and customs of its host country at the expense of their own native culture. For a long time, this was a process that defined earlier, largely European immigrant streams. Also referred to as a linear, or unidirectional process of acculturation, many studies continued to similarly characterize this process among newer, more ethnically distinct immigrant waves. Theorists however began to frame the process among these newer immigrant groups as one that was more multidimensional and dynamic and that did not necessarily involve complete disentanglement from one's own culture. More complex theoretical models of acculturation were offered, including ones that allowed for a more bicultural orientation where one's native heritage may be retained at the same time one may be fully integrated into the mainstream culture (12).

The most common models for acculturation in public health however remain linearly oriented, utilizing single-measure proxies such as nativity, language, and years in U.S. to capture the construct (9). The assumption is not that these single measures are directly responsible for causing poor health, but rather it is the underlying processes that that they represent that may be operating to alter health behaviors. Several other scales have also been developed with more bi- or multi-dimensional orientations that aim to incorporate elements such as attitudes, values, and ethnic interaction, as well as more detailed information about language use in various work and social settings (13, 14). Critics nevertheless maintain that none of these constructs aptly measure the dynamic and

multi-dimensional nature of the process. Convenience and availability of proxy variables has largely driven their use in health studies.

Despite the limitations of currently available measures of acculturation, their utility is more likely to be based on research goals and the types of questions that are being asked. Simpler measures, for example, are not appropriate to measure changes in values, beliefs, and attitudes nor to gain a better grasp of the nuances of culture and its relation to health. However they may be useful as simple descriptors for describing the heterogeneity in immigrant populations, and as a basis from which investigators can begin to tease apart the relationship linking acculturation to health (9). Other investigators have also stressed the importance of including important modifiers to better account for variation in this relationship. Some recommendations put forward include accounting for contextual factors both prior to immigration, such as society of origin factors, and after immigration, such as settlement factors and geographic residence (11). While measurement of acculturation remains imperfect, utilizing available measures together with the inclusion of modifiers may provide additional clarity into the processes related to health that may be operating in the context of migrations and settlement (15).

Review of the evidence

Comparative studies assessing the health status of immigrants and the native-born population have been done on a range of health outcomes, including mental health, infant mortality, hypertension, obesity, diabetes, and associated health behaviors, such as diet and physical activity. Specifically with respect to BMI and adiposity, established risk factors for cardiovascular disease, most studies lend support to the hypothesis that

acculturation is associated with an increase in obesity however a select few either report null results, or an inverse relationship. Some of the mixed results may be attributed to diversity in the assessment of acculturation, variation in the ethnic group under study, quality of the outcome being measured (self-report vs. measured BMI), and the inclusion/exclusion of relevant confounders and modifiers. Most studies are cross-sectional, and are reviewed below with distinctions made by study design, acculturation measure used, and immigrant subgroup.

Years in U.S. and Nativity

A review by Oza-Frank et al. effectively synthesizes the literature examining the relationship between years in the U.S. and weight among immigrants of all races. Fifteen articles were reviewed, all cross-sectional studies, with fourteen reporting an overall significant positive relationships between time in U.S. and body weight, though modification of this relationship is observed by race (16). All but one of these studies assessed the outcome, BMI, by self-report (17). Among Hispanics, results consistently demonstrated a higher BMI or obesity prevalence with more time in the U.S, however results were mixed for other racial/ethnic groups. In a study of California residents, investigators reported no clear pattern with time in the U.S. among Asians, and an inverse relationship among foreign-born Whites (18). An examination comparing foreign-born to U.S. born residents in NYC also revealed significantly higher BMI among U.S. born Hispanics, but null results among Asians (19). In contrast, Lauderdale et al. documented a significant positive relationship among all Asian ethnic subgroups, though the magnitude varied by ancestry (20).

Two other studies utilized repeated cross-sections from the National Health Interview Survey (NHIS) to create synthetic cohorts by race/ethnicity to examine changes in BMI by immigrant cohort, and age at arrival cohorts (21, 22). In both papers, investigators attempted to separate the effect of duration of residence from cohort effects. A key finding in one of the studies was a marked gradient in increasing BMI with increasing time in the U.S. among Hispanics and Blacks, and no statistically significant change among Whites and Asians. There was also a significant interaction with age at arrival, demonstrating a stronger relationship between time in US and BMI for those who migrated younger (22). In the second paper, no differences by immigrant cohort were observed over time such that all cohorts by race (Asians were not examined), except for White females, exhibited a lower BMI than their respective native-born racial comparison. Results also revealed a higher BMI with time in U.S. for all race groups, however, only Hispanics converged and actually surpassed the BMI levels of the native-born (21).

Language:

A number of studies have also assessed the relationship between acculturation and BMI using primary language spoken as a single-variable proxy. All reviewed studies were cross-sectional in nature and results were generally mixed. In a study of Hispanics using the Hispanic Health and Nutrition Survey (HHANES), investigators reported a weak association between language preference and measured BMI overall, however results were also conditional on subgroup with significant associations found among Mexicans, but not among Cubans, or Puerto Ricans. Also, inconsistent with expected

findings, a lower BMI was associated with English preference specifically among women (23). In two separate studies using NHANES data, one demonstrated lower measured waist circumference among Mexican-born Spanish speakers, followed by Mexican-born English speakers, with the highest waist circumference levels observed among U.S. born Spanish speakers (24). A second study however reported lower BMI among Mexican Spanish speakers than among English speakers (25). Among other racial/ethnic groups, only one study assessing language was found among Chinese, which demonstrated conflicting evidence - use of English language was associated with lower BMI yet longer residence was associated with higher BMI (26).

Other acculturation indicators:

A number of other studies have utilized other acculturation indicators such as generation, scales, or a combination of indicators. In one cross-sectional study of generation using a sample of Latino and Asian adults, higher generation was associated with higher BMI for most subgroups but not all, with differences particularly noted for Vietnamese adults who demonstrated lower BMI with increasing generation (27). Also in contrast to expected findings, one study that measured acculturation using scale measures documented a decrease in obesity levels with increasing acculturation among Mexican-Americans (28). Possibly relevant however were the data years under study, 1979-1982.

Longitudinal studies

Only one prospective study was found, which was conducted using a multi-ethnic cohort of children. This study examined the inter-relationship among generation, GDP per capita of child's country of origin, and SES, and the association with BMI. Results

showed a positive association between generation and weight gain only among lower SES children from low-income countries (29).

Limitations in the Literature

Although much of the literature lends general support to the relationship linking greater acculturation to obesity, there is considerable variation for which many studies fail to account. Even within more recent waves of immigration of the past 20 years, there remains an enormous amount of heterogeneity, even among the 2 largest immigrant majorities, Latinos and Asians. Various immigrants group may be motivated by different social, economic or political reasons for migrating, and are subject to, depending on age at arrival and time since arrival, influences of both the context in which they ultimately settle, and their place of origin (12, 27). Another factor contributing to some of the inconsistent results is the cross-sectional nature of most studies, which precludes the ability to rule out cohort effects and temporal trends that may be driving the relationship. To address some of the limitations that have been faced by previous studies, this dissertation contributes to this line of research by addressing issues specific to ethnicity/country of origin, temporal trends, and neighborhood of residence.

Ethnicity/Country of origin

Studies that have investigated the association between acculturation and chronic health outcomes are often based on the assumption that immigrants originate from countries where lifestyle behaviors associated with development of chronic disease are less prevalent than in more developed countries such as the U.S. (1) The association between acculturation and adiposity, however, may differ depending on the lifestyle

habits, nutrient availability, and/or health profile of the sending country. In light of rising global trends in obesity, it may be that immigrants' adiposity could be more reflective of health and development patterns in their country of origin rather than a problem that independently arises with increasing exposure to the U.S. context. This underscores the importance of considering variation by ethnicity or country of origin.

In many developing countries, unhealthy lifestyles related to poorer diets, and more sedentary lifestyles, along with rising life expectancy and changing socioeconomic environment have contributed to an escalating obesity problem (30). Also referred to as the nutrition transition, a process whereby societies converge towards diets high in saturated fats, sugar, and refined foods, accompanied by lower levels of activity, there is evidence that the rate of this transition is rapidly occurring in lower and middle-income developing countries (31). A range of factors, including urbanization, economic growth, and culture, are all thought to be driving this change. Examples of countries marked by accelerated transitions include China, Mexico, Thailand, and Indonesia (32).

In recognition of these global trends, researchers have begun to consider that the relationship between acculturation and obesity and mediating health behaviors may also be influenced by the way the behaviors are performed in the country of origin prior to moving to the U.S. (5, 12). After migration, factors associated with the receiving environment into which immigrants settle, the political, economic, and social context, as well as discrimination and legalization obstacles that may be faced by distinct groups may all contribute to shape differential health trajectories based on ethnicity or country of

origin (33). Studies that aggregate Latinos and Asians as two pan-ethnic groups fail to account for this level of heterogeneity.

Calendar time

Influences associated with the development of global obesity are also apt to drive variation in the association between acculturation and adiposity across calendar time. The vast majority of studies have examined this relationship at a single point in time, which obscures aging and birth cohort effects, and does not allow for investigation of secular trends. In light of rising secular trends in obesity, both domestically and on a global level, some investigators have recognized that what are being interpreted as acculturation effects may actually be a reflection of changes occurring from within an immigrant's host country (19). Moreover, in a world of increased globalization, it has also been suggested that more recent migrants may already have more exposure to Western influences and lifestyle behaviors than in previous decades which may also function to alter the relationship between acculturation and obesity (33). Although exposure to the U.S. context may have once had an effect on the BMI of immigrants, it remains unclear if this relationship continues to hold in more recent calendar years in light of these emerging trends.

Neighborhood Context

Links to Obesity and Health Behaviors

It has also been suggested that the social and physical context of settlement regions should also be considered in studies investigating immigrant health. Where immigrants settle may have implications for individual-level dietary and physical activity

patterns which may in turn contribute to overweight and obesity. There is growing literature on the contribution of the neighborhood environment to obesity, though results have varied depending on the neighborhood scale considered and the population under study (34, 35). In a study using neighborhood data from the Multi-Ethnic Study of Atherosclerosis (MESA), residents living in neighborhoods with better physical environments, defined by walkability and healthy food availability, had a lower BMI, though analyses of the social environment produced a less consistent relationship (36). A systematic review of neighborhoods and obesity conducted by Black et al, revealed consistent associations among studies between neighborhood-level measures of economic resources and obesity, but mixed results between neighborhood income inequality and racial composition and obesity (35).

There is also evidence linking structural features of the residential context, such as healthy food availability and resources for physical activity, and its influence on the actual health behaviors that are thought to mediate the relationship between neighborhood and obesity. Much of the evidence points to a positive association between resources for healthy food and physical activity and better quality diets and increased likelihood of engaging in exercise (37, 38).

Neighborhoods and Immigrants

Despite the number of studies investigating the links between residential context and obesity and related health behaviors, very few have explored this relationship among immigrants. A review by Papas, et al. highlighted the dearth of studies on the built environment and obesity on populations other than non-Hispanic Whites and African-

Americans, and a lack of longitudinal studies in general (34). Immigrants may be a distinct group from the native-born in that they may bring with them a different set of cultural norms and perceptions. It remains unclear though how neighborhood-level features may be relevant to health patterning for immigrants, as well as for native-born Hispanics and Asians. Explanations for the observed health deterioration among immigrants have pointed to structural features that may force a change in diet and other lifestyle factors that would have otherwise been protective against negative health outcomes. Very few studies however have investigated whether 'better' neighborhood environments as characterized by positive physical and social features have the same impact on immigrants as may be the case in studies of native-born individuals. The presence of facilities for recreation, for example, may not translate into increased physical activity and subsequent weight maintenance or loss if use of such facilities is not culturally appropriate. On the other hand, structural forces may be strong enough such that maintenance of traditional diets is all but impossible in settings where food availability is limited to fast-food restaurants or convenience stores.

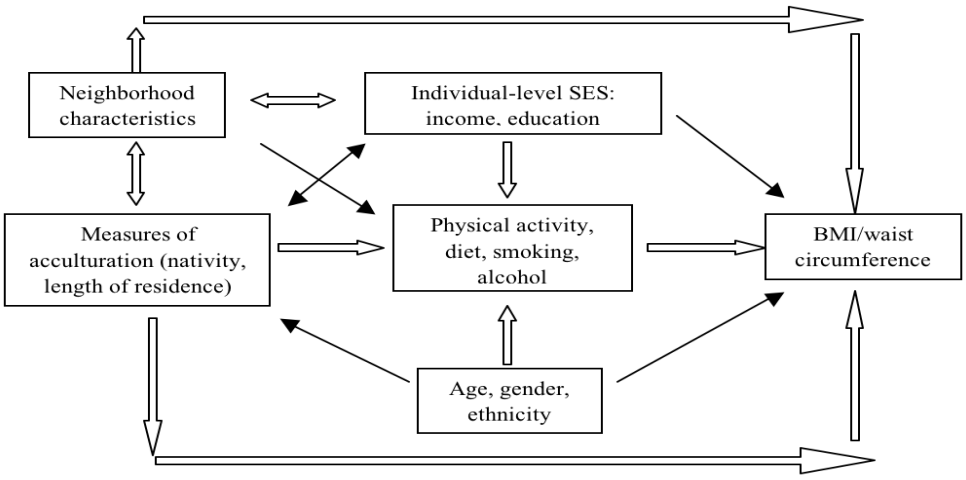
Among studies that have explored neighborhood links among immigrants, most have investigated the association between neighborhood racial composition and health behaviors. In some studies, higher percentage of foreign-born population within a census tract was associated with healthier individual-level diets (39, 40). However, an inverse association was also found with physical activity (40). One study that used nationally representative data from NHANES noted an increase in BMI with an increase in Hispanic composition of the neighborhood among Mexican-Americans, although a strong positive

association between neighborhood disadvantage and BMI was also observed (41). While a causal relationship between increasing time in the U.S. and obesity has been difficult to establish, if there is indeed a causal component linking features of the U.S. context to adverse weight outcomes, it will be important to disentangle this relationship through, among other strategies, investigations into the context in which immigrants ultimately reside. Given that structural features of the context in which immigrants settle have implications for both acculturation and for obesity outcomes, it will be important to take these into account in investigations of the immigrant experience in the U.S. Further disaggregation of neighborhood indicators will also be important to promote a better understand of how neighborhoods play a role in the relationship between acculturation and obesity among immigrant groups.

Conceptual Model

This dissertation is built on the overall framework that the association between measures of acculturation and weight is not monolithic across groups, and can vary depending on ethnicity (Aim 1), the neighborhood environment (Aim 2), and calendar time (Aim 3). The following conceptual model was used to guide analyses for this dissertation:

Figure 1.1: Conceptual model
Note: Unidirectional arrows indicate a hypothesized causal relationship. Double-headed arrows indicate variables that are associated with each other, but not necessarily causally.



Longitudinal data were used for the first two aims. In the first aim, the relationship between nativity/length of residence and waist circumference (WC) among Hispanics and Chinese was examined from a prospective standpoint using data from the Multi-Ethnic Study of Atherosclerosis (MESA). Variation by ethnicity, or Mexican-origin status, was also investigated among Hispanics. In the second aim, analyses were restricted to Hispanics and Chinese on whom neighborhood data were available. In the third aim, secular variation in the relationship between nativity/length of residence and body mass index (BMI) and waist circumference (WC) was examined using repeated cross-sectional data from the National Health and Nutrition Examination Survey (NHANES) spanning a period of 20 years. Analyses were restricted to Mexican-American adults to permit quantification of this relationship among the largest immigrant group in the U.S.

Chapter 2

Immigrant assimilation and waist size over time: a longitudinal examination among Hispanic and Chinese participants in the Multi-Ethnic Study of Atherosclerosis (MESA)

Introduction

Over the past 20 years, the U.S. has experienced tremendous growth of its foreign-born population, especially immigrants from Latin America and Asia. By 2025, immigrants are projected to account for 15% of the U.S. population (42). The increasing presence of this unique and heterogeneous group 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 in the foreign-born than in the U.S.-born despite comparatively low socioeconomic position (18-20, 43, 44). However, a longer length of U.S. residence has been associated with higher weight in immigrants, in some groups converging with levels observed in the U.S.-born (16, 17, 21, 45, 46). Acculturation to behavioral norms prevalent in U.S. society, such as poor diet and sedentary lifestyle, is thought to explain this relationship (11).

However existing research is primarily cross-sectional which does not allow examination of longitudinal change over time, and may conflate cohort or age effects

with the effects of time in the U.S. Conclusions drawn about the impact of length of U.S. residence derived from cross-sectional studies assume that the health characteristics of newly-arrived immigrant cohorts have remained stable over time. Variability in immigrant selection processes and greater exposure to Western lifestyle behaviors over time within many sending countries may invalidate this assumption (32, 33). Another challenge is separating the effects of longer U.S residence from those of age-related and secular increases in adiposity, which have been occurring in the U.S. across all segments of society (47-49). As a result, the cross-sectional observation that immigrants living in the U.S. longer have higher weight, may merely be a function of secular trends in weight, rather than, as some studies suggest, an independent product of greater length of U.S. residence. Prospective data are critical to determine whether immigrants' weights are increasing with longer U.S. residence at a rate faster than would be expected given overall age effects and secular trends observed in the U.S. population (50).

Although several studies have examined heterogeneity in these relationships by race, few have explored differences by ethnic subgroup (18, 27). Variation by ethnicity may be a function of exposures occurring within the countries of origin before immigration, and of features of the receiving environments into which immigrants migrate. Among Hispanics, for example, Mexican-Americans have been disproportionately impacted by obesity relative to other Hispanic subgroups (32, 51, 52). Whether the weight of Mexican-origin Hispanics is differentially influenced by greater exposure to the U.S. context relative to other Hispanics is unknown.

We used longitudinal data from the Multi-ethnic Study of Atherosclerosis (MESA) to examine whether Hispanic and Chinese foreign-born participants experienced greater increases in waist circumference (WC) over a median follow-up of 5 years relative to their U.S.-born counterparts. We also explored heterogeneity in this association by Hispanic subgroup.

Methods

Study population and variables

MESA is a prospective cohort study designed to investigate risk factors for subclinical cardiovascular diseases (CVD). Details on the design of MESA are provided elsewhere (53). In brief, participants aged 45-84 years, free of clinical CVD at baseline were recruited from six study sites (Baltimore, Maryland; Chicago, Illinois; Forsyth County, North Carolina; Los Angeles County, California; northern Manhattan, New York; and St. Paul, Minnesota). The MESA cohort includes 6814 individuals who self-identified as white, African-American, Hispanic or Chinese-American. The baseline examination took place between 2000 and 2002. Participants attended three follow-up examinations approximately 18-24 months apart. These analyses were restricted to Hispanic and Chinese participants because of the limited number of foreign-born individuals for other race/ethnic groups.

Waist circumference (WC) (cm) was measured at baseline and at each follow-up visit using standardized procedures. We chose WC as our anthropometric measure of interest because it is a strong marker of metabolically active visceral adiposity and is closely associated with an increased risk for CVD (54, 55). For descriptive purposes, WC

was also dichotomized based on the World Health Organization's criteria for 'high risk' for metabolic syndrome (56). Information on nativity (U.S. vs. foreign birth), number of years lived in the U.S. among the foreign-born (<15 years, 15-30 years, >30 years, missing), age (continuous, centered at the mean baseline age of 63), sex, race/ethnicity (Hispanic, Chinese), education (less than high school, high school diploma, some college/technical school, college graduate), and income (in 13 categories ranging from <$5,000 to $100,000+) was obtained during the baseline interview. Among Hispanics, ethnicity was further disaggregated into self-reported Mexican-origin status (yes/no). Those of Mexican origin represent the largest segment of the Hispanic population and are the largest U.S. immigrant group overall (57, 58). The limited sample size of U.S.-born non-Mexican Hispanics did not permit disaggregation of this subgroup. Baseline income was available for 97.6% of Hispanics and 99.3% of Chinese. When missing, income data from follow-up exams were used (1.7% of Hispanics; 0.62% Chinese). Participants selected their total family income from all sources within the past 12 months from 13 categories; a continuous measure of household-equivalized income was created by taking the midpoint for each category and dividing it by the number of people in the household. The variable was then categorized and expressed as quartiles of the sample distribution. Time since baseline, in years, was used to examine change in WC over time.

We also tested whether lifestyle behaviors mediated associations between WC with nativity and length of U.S. 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 3 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 (59). Diet was measured at baseline using an adapted 120-item food frequency questionnaire, validated for multi-ethnic populations (60). We operationalized diet in two ways: total caloric intake (kilocalories) 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 (61). Higher scores indicate higher intake of fats and processed foods (fats, oils, processed meats, fried potatoes, salty snacks, and desserts).

Of the 2299 Hispanic and Chinese MESA baseline participants, 11 did not have complete information on key covariates of interest, yielding a sample of 1486 Hispanic (794 Mexican, 692 non-Mexican) and 802 Chinese participants. Mediation analyses using diet were further restricted to 1350 Hispanics and 790 Chinese because of missing diet data. Of the 2288 baseline sample, 77% had information for all four visits, 13% had information for two or three visits, and 7% had information only for the baseline visit. Longitudinal analyses included all 2288 baseline participants regardless of missing information at follow-up. All MESA participants provided written informed consent.

Statistical Analysis

All results were stratified by race/ethnicity (Hispanics and Chinese). We used graphical methods to explore the relationships between WC, age, and time since baseline, and confirmed linearity of these relationships (62). We estimated cross-sectional and longitudinal associations between nativity and WC using a repeated measures analysis

with the unstructured covariance specification to account for within-person correlations (63) (PROC MIXED SAS 9.2; SAS Institute Inc., Cary, NC). Models were adjusted for baseline age, sex, study site, education, income, and time since baseline. An interaction between time and baseline age was retained because changes in WC over time differed significantly by baseline age with greater increases over time among participants younger at baseline. We also included time interactions with education and income to adjust for differential trends over time by socioeconomic factors. To evaluate if changes in WC over time varied by nativity, we tested a cross-product term between nativity and time (Table 2.2). We also examined the potentially mediating effect of physical activity, smoking, alcohol, and dietary factors on the relationship between nativity and WC by including these measures in models as time-varying covariates when available. Since dietary information was only ascertained at baseline, we modeled its interaction with time in lieu of a time-varying covariate. To examine heterogeneity in nativity associations with WC by Hispanic subgroup, we included a covariate for Mexican-origin status in Hispanic models. We modeled it as a two-way interaction with nativity and with time, and as a three-way interaction between Mexican-origin (non-Mexican=referent), nativity (U.S.-born=referent), and time (Table 2.3). For all models, we computed estimates of adjusted mean annual change in WC by nativity (Tables 2.2 and 2.3) and by Mexican-origin (Table 2.3) using model coefficients.

To further examine whether WC changes over time differed by time lived in the U.S. at baseline, we also fit models that replaced the nativity indicator with a 5-level variable that combined birthplace and baseline length of U.S. residence among the

foreign-born (FB) (FB: < 15 years; FB: 15-30 years; FB: > 30 years; FB: missing years in U.S.; and U.S.-born (referent)). We tested an interaction between this 5-level variable and time in models stratified by ethnicity.

Since approximately 23% of our sample did not have complete information on all four study visits, we re-ran all models on only 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 WC trajectories among individuals lost to follow-up did not differ from those who remained in the study.

Results

Descriptive analyses

Foreign-born (FB) Hispanic and Chinese participants had lower baseline WC measurements than their U.S.-born (USB) counterparts (mean WC for FB and USB Hispanics: 99 vs. 103 cm, P <0.0001; and Chinese: 87 vs. 92 cm, P=0.09), and had a lower proportion of individuals with WC measurements classified as 'high risk' at baseline (Table 2.1). The foreign-born also had greater 5-year mean increase in WC though differences were not statistically significant (comparing FB to USB: Hispanics: 1.75 vs. 1.08 cm, P=0.09; Chinese: 1.21 vs. 0.26 cm, P=0.40). Foreign-born participants were disproportionately represented in the lowest education and income categories, and had lower levels of physical activity, but more favorable profiles for diet, smoking, and alcohol consumption compared to the U.S.-born. Nativity differences among Hispanics were generally similar regardless of ethnicity with a few exceptions. First, the nativity difference in baseline WC was slightly smaller among Mexican Hispanics. Second, the

proportion of women with high-risk WC was higher among foreign-born Mexicans compared with the U.S.-born, whereas this pattern was reversed among non-Mexican Hispanics. Finally, SES disparities by nativity were considerably wider than those among non-Mexican Hispanics.

Multivariable analyses

Table 2.2 shows adjusted mean differences in baseline WC and in annual change by nativity for Hispanics and Chinese. After accounting for age, sex, site, education, income, and time (Model 1), the foreign-born had a significantly lower mean baseline WC than the U.S.-born (Hispanics: mean difference=-3.66, P<0.001; Chinese:-5.13, P<0.01). All groups except U.S.-born Chinese experienced significant increases in WC over time, but there were no significant differences by nativity in either ethnic group. Inclusion of time-varying measures of physical activity, smoking, and alcohol (Model 2) slightly increased nativity differences in baseline WC, but addition of baseline dietary measures (Model 3) partially reduced this difference for both Hispanics and Chinese.

Tests for interaction revealed significant heterogeneity by Mexican-origin among Hispanics (Likelihood ratio test: P=0.0082) (Table 2.3). 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 4 Mexican-origin and nativity combination groups experienced WC increases over time, the Mexican foreign-born experienced greater increases over time compared to both the Mexican U.S.-born (difference in mean annual change=0.28, P<0.05), and the non-Mexican foreign-born (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 U.S.-born persons. Inclusion of health behaviors did not meaningfully alter estimates (Model 2).

Ethnicity-stratified models were re-examined using a multi-category indicator to capture both place of birth and time in the U.S. for the foreign-born. Figure 2.1 (A-C) present trends over time in adjusted mean WC by baseline length of U.S. residence. Among Mexican Hispanics, only the most recent immigrants (<15 years since arrival) have a significantly lower baseline mean WC than the U.S.-born (Fig. 2.1A) (mean difference=-3.77, P=0.0470). Over time, however, rates of increase for this group were significantly greater than for the U.S.-born (mean difference in annual change=0.48, P<0.0236) so that after 5 years, their WC estimates no longer statistically differed from the U.S.-born. Although the other Mexican immigrant groups did not differ from the U.S.-born with respect to baseline WC, they also had a significantly greater rate of increase; in some cases surpassing Mexican U.S.-born estimates by the end of available follow-up**.**

Among non-Mexican Hispanics, the baseline WC of the foreign-born was significantly lower relative to the U.S.-born, regardless of length of U.S. residence, but there were no differences in WC change over time (Fig. 2.1B). We also observed a similar pattern for the Chinese (Fig. 2.1C). However when we restricted analysis to only the Chinese foreign-born, WC gains over time among more recent immigrants (<15 years and 15-30 years) were significantly greater than for immigrants in the U.S. longer than 30 years.

We also considered heterogeneity in these relationships by sex but only observed a significant interaction among Mexican Hispanics. Baseline nativity differences in WC were smaller and not significant among females compared to males; although both male and female foreign-born Mexicans experienced greater increases in WC relative to the U.S.-born, the magnitude was significantly larger for females (data not shown).

Discussion

We sought to examine differences in WC and WC change by nativity and ethnicity in a prospective multi-ethnic cohort. Foreign birth was associated with a lower adjusted mean baseline WC among both Hispanic and Chinese participants. Although there were no significant time trend differences by nativity for either ethnic group, there was significant heterogeneity within the Hispanics sample. Among Mexican Hispanics, baseline nativity differences in WC were narrower than they were for non-Mexican Hispanics, particularly among females. Foreign-born Mexicans also experienced greater annual mean increases in WC than both U.S.-born Mexican and foreign-born non-Mexican Hispanics.

Consistent with our baseline results, prior cross-sectional work has documented lower weight in the foreign-born than the U.S.-born across race/ethnic groups (18, 21, 22, 43, 64). These findings extend to Hispanics (18, 19, 21, 22, 44, 50, 65) and Mexican-Americans (23, 66-69). Among Asian-Americans, foreign-birth is also predominantly associated with lower weight (18, 20, 22, 43, 65, 69), though null findings have also been reported (19, 26). Previous studies, primarily among Hispanics and Mexican-Americans, have also noted smaller weight differences by nativity among females than males, and

faster convergence among female migrants to U.S.-born weight levels, supportive of our findings among Mexican women (7, 18, 21, 45, 46, 66).

Results from cross-sectional studies examining associations between length of U.S. residence and weight measures however are varied. Among Hispanics, many nationally-representative studies show evidence of higher BMI, WC, or obesity with longer U.S. residence (16, 21, 43-45). Region-specific studies (18, 19, 70), as well as studies specific to Mexican and Puerto Rican subgroups (17, 66) support these findings. In contrast, results among Asians are mixed (18, 20). To our knowledge, no longitudinal studies have directly examined the relation between time in the U.S. and changes in weight over time.

A major limitation in drawing inferences regarding the causal effect of time in the U.S. on weight from cross-sectional analyses is the inability to differentiate the true effects of time in the U.S. from cohort and aging effects. Controlling for baseline age and the interaction of age with time in a longitudinal design, we were able to directly examine whether the foreign-born experienced gains in WC with longer time in the U.S. relative to the U.S.-born, net of age and birth cohort effects. Contrary to the cross-sectional literature that did not account for these effects, we did not find evidence of greater WC increases over time among foreign-born Hispanics and Chinese. Nevertheless, our results were consistent with one cross-sectional study of Hispanics that used a series of repeated cross-sections to trace foreign and U.S.-born age cohorts simultaneously over a period of 10 years. Accounting for the effects of age, calendar time, and their interaction, investigators found no evidence of foreign-born weight convergence to U.S.-born levels,

consistent with our Hispanic findings (50). Failure to distinguish by subgroup however masks heterogeneity among Hispanics; our analyses revealed WC convergence over time among Mexican immigrants to U.S.-born levels, with a greater magnitude of increase among females.

Reasons underlying the increase in WC among foreign-born Mexicans remain unclear. Adoption of negative health behaviors has been hypothesized to account for the increased weight associated with longer length of U.S. residence, however inclusion of behavioral covariates in models did not fully account for our findings (11). 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 capture a key explanation for the patterns found among foreign-born Mexican Hispanics. 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.

Much of the literature associates greater length of U.S. residence with decline in health among immigrants. However, it is also recognized that time in the U.S. is a proxy for a complex set of interactions that include, but are not limited to, exposure to differential cultural and socio-political features of the host country environment, variation in opportunity for socioeconomic advancement, and the influence of characteristics associated with a migrant's country of origin (10, 11). The ethnic heterogeneity we observed in WC increase with greater longitudinal time in the U.S. may provide evidence that the acculturation process may not be homogeneous for all Hispanics, let alone other

immigrants. Migration to and residence in environments marked by poverty, crime, and deficiency in physical and social resources, may reinforce poorer health behaviors, facilitating a more rapid decline in health (34, 71). Although it is unclear if foreign-born Mexicans are more likely to be negatively exposed to such contexts and stressors than other ethnic groups, future exploration of the impact of contextual features could provide additional insight into the factors underlying the diverse health trajectories experienced by different immigrant groups.

There are also potential methodological explanations for the greater WC increases among foreign-born Mexican Hispanics. Despite the robustness of our complete-case analysis, if greater loss to follow-up among the foreign-born 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 WC in multivariable models. The extent to which baseline WC should be controlled for in models estimating change over time is debatable, especially when the variables of interest are associated with the baseline measurements (72). However, since the most notable change-estimate differences were between groups with small differences in baseline measurements, we found no compelling reason to include it as a covariate.

We observed an accelerated WC increase among more recent foreign-born Mexican Hispanics and Chinese immigrants. Previous studies find that associations between length of U.S. residence and health are largest within the first 10-15 years of arriving to the U.S., attributing these findings to the stress of migration and sudden cultural change that diminishes after a period of adaptation (21, 73). However, it is also

among the most recent immigrants that the influence of one's country of origin may be particularly salient. For example, among immigrants from countries where the obesity epidemic rivals that of the U.S., such as Mexico, or countries rapidly transitioning to a lifestyle of energy-dense diets and sedentary activity, such as China, behaviors established in the sending country may remain important influences after migration (31). Moreover, there may be patterns of return migration to reinforce such norms and behaviors, especially among Mexican immigrants. As more sending countries become characterized by high obesity prevalence, future immigrant cohorts may no longer exhibit protection against the higher weight associated with U.S. birth, especially when coupled with poverty and discrimination stressors.

Our study had some limitations. Grouping non-Mexican Hispanics may have masked important patterns, however small cell sizes limited power for additional subgroup analyses. The small number of U.S.-born Chinese may have also precluded our ability to detect nativity differences. Future studies with larger samples of U.S.-born Chinese and Hispanic subgroups are warranted to confirm our findings. We also had a relatively short timeframe for assessing longitudinal relationships. For many individuals, both change in WC and the causes of those changes may have already occurred prior to baseline. Finally, because MESA is an older, healthy cohort sampled from selected sites, the generalizability of these findings to other immigrant groups in the U.S. may be limited.

To our knowledge, this among the first studies to examine the relationship between longer length of U.S. residence and adiposity longitudinally using a multi-ethnic

cohort. We found heterogeneity by ethnic group in rates of WC increase over time with Mexican immigrants exhibiting greater increases in WC relative to both U.S.-born Mexican Hispanics and foreign-born non-Mexican Hispanics. Since high WC levels have consequences for progression to CVD and other metabolic abnormalities, it remains an important target for intervention. Further insight into what may underlie these patterns would facilitate development of interventions to prevent the health deterioration that appears with longer time in the U.S. in some groups.

Table 2.1. Sample Characteristics by Nativity and Ethnicity

	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 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)
High-risk waist circumference, baseline (%)								
Men: ≥ 102 cm**	48.4	37*	48.8	37.4*	45.2	36.7	17.6	7
Women: ≥ 88 cm **	82.2	80.3	80.8	88.7*	90.3	75.3*	53.8	40.8
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
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.$ † (%)								
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)‡	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)‡	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

Abbreviations: SD, standard deviation; MET, metabolic equivalent task

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

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

†Continuous measure of income adjusted for household size, expressed as quartiles

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

Table 2.2. Adjusted Mean Difference at Baseline and Mean Annual Change in Waist Circumference (WC) (cm) by Nativity, Hispanics and Chinese

	Model 1	Model 2	Model 3
HISPANICS (n=1486)			
Mean difference in baseline WC			
U.S. born	ref	ref	ref
Foreign-born	-3.66 (0.87)****	-3.76 (0.87)****	-3.42 (0.93)***
Mean annual change by nativity†			
U.S. born	0.28 (0.11)**	0.25 (0.11)*	0.28 (0.11)*
Foreign-born	0.39 (0.07)****	0.39 (0.08)****	0.38 (0.08)****
Mean difference in annual change			
U.S. born	ref	ref	ref
Foreign-born	0.11 (0.08)	0.14 (0.08)	0.11 (0.09)
CHINESE (n=802)			
Mean difference in baseline WC			
U.S. born	ref	ref	ref
Foreign-born	-5.13 (1.83)**	-5.23 (1.84)**	-4.78 (1.95)*
Mean annual change by nativity†			
U.S. born	0.24 (0.23)	0.24 (0.23)	0.16 (0.24)
Foreign-born	0.37 (0.10)***	0.36 (0.10)***	0.33 (0.11)**
Mean difference in annual change			
U.S. born	ref	ref	ref
Foreign-born	0.13 (0.21)	0.12 (0.21)	0.17 (0.22)

****p < 0.0001, ***p < 0.001, **p < 0.01, *p < 0.05

Model 1 further adjusted for age, sex, site, baseline education and income, time since baseline, and interactions for age*time, education*time, and income*time

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 1350 Hispanics and 790 Chinese on whom dietary data was available. Sensitivity analyses confirmed that results from previous models excluding missing dietary data did not appreciably affect results.

Table 2.3. Adjusted Mean Waist Circumference (WC) (cm) at Baseline and Mean Annual Change in WC by Nativity and Mexican Ethnicity

	Model 1			Model 2†		
	Adjusted mean baseline WC (SE)‡		*Mean difference in baseline WC by nativity (SE) ξ*	*Adjusted mean baseline WC (SE)‡*		*Mean difference in baseline WC by nativity (SE) ξ*
	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)€	-3.94 (1.89)*	1.74 (1.14)		-4.01 (1.99)*	1.10 (1.15)	
	Adjusted mean annual change (SE)‡		*Mean difference in annual change in WC by nativity (SE)ξ*	*Adjusted mean annual change (SE)‡*		*Mean difference in annual change in WC by nativity (SE)ξ*
	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)****	0.28 (0.12)*
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)€	0.10 (0.18)	0.24 (0.09)**		0.15 (0.20)	0.26 (0.10)**	

****p < 0.0001, ***p < 0.001, **p < 0.01, *p < 0.05

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)

†Model 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

‡Adjusted 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.

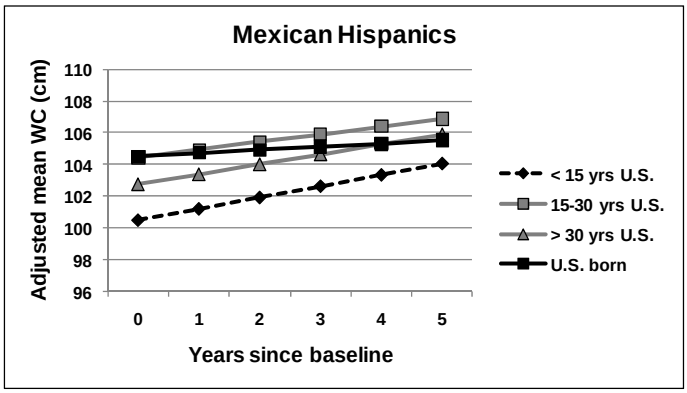
ξCompares foreign-born to U.S.-born referent for each Mexican-origin group

€Compares Mexican to Non-Mexican referent for each nativity group

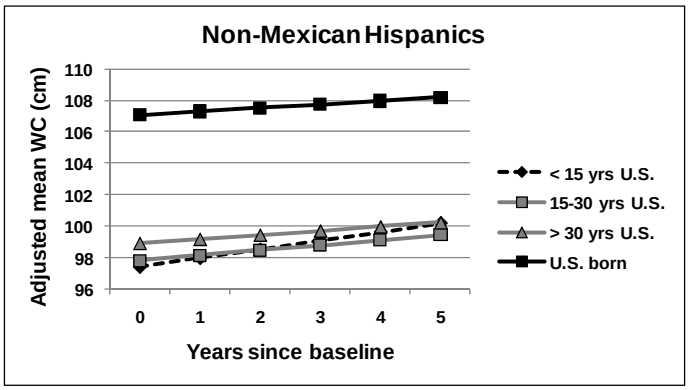
Likelihood ratio test comparing nested models with and without interaction terms for Mexican ethnicity: p = 0.0082

Figure 2.1. Adjusted mean waist circumference trajectories over time by baseline length of U.S. residence among the foreign-born vs. U.S.-born

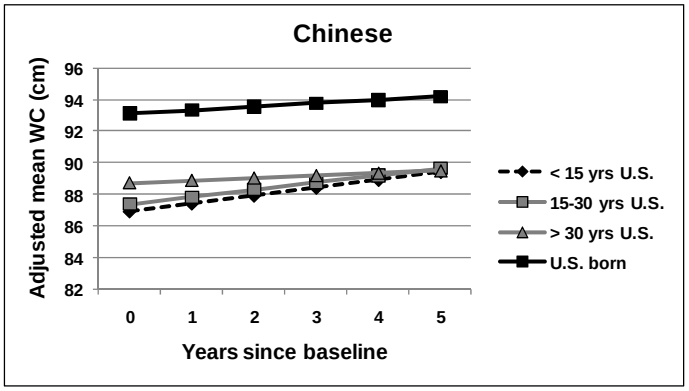
A)



B)



C)



A) Mexican Hispanics, B) Non-Mexican Hispanics, C) Chinese. WC=waist circumference. All models further adjusted for age, sex, site, education, income, baseline length of U.S. residence, age*time, education*time, income*time, baseline length of U.S. residence*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 U.S. residence included in all models but not plotted in figures.

Chapter 3

The neighborhood environment as a modifier of the association between nativity/length of U.S. residence and waist circumference among Hispanic and Chinese participants in the Multi-ethnic Study of Atherosclerosis (MESA)

Introduction

Over the last two decades, the U.S. has experienced one of the largest waves of immigration in its history. According to estimates from 2007, 37.3 million U.S. residents were born outside the country, representing 12% of the population (8). Though the demographic composition of immigrants has varied over time, the majority of contemporary immigrants now originate from non-European countries (74).

In light of the growth and changing demographics of immigration, several studies have explored health patterns among the foreign-born relative to U.S born, documenting a health advantage among the foreign-born that appears to erode with longer time in the U.S. (16, 20-22, 43) Past research suggests that the adoption of negative health behaviors is one mechanism through which increased acculturation, often proxied by nativity and/or length of U.S. residence, may be associated with increased weight, for example (7, 21). However, the vast majority of studies have been cross-sectional, and few have examined the role of contextual characteristics (such as neighborhoods) in the relationship between acculturation and anthropometric outcomes.

An immigrant's risk of obesity may be shaped not only by influences related to their country of origin, but also by the residential context to which they migrate. Residential environments may have implications for individual-level dietary and physical activity choices which can contribute to overweight and obesity. There is growing literature on the contribution of the neighborhood environment to obesity in general, but results are varied depending on the neighborhood construct examined and the population under study (34, 35). In one study, residents living in neighborhoods with better physical environments, defined by perceived walkability and healthy food availability, had a lower mean body mass index (BMI) (36). In other work, structural features of the environment such as the presence of supermarkets or fast food establishments were associated with obesity prevalence (75, 76). Longitudinal studies are limited. However one study demonstrated no association between neighborhood walkability and BMI change, but an inverse association between neighborhood socioeconomic status (SES) and BMI change (77).

Few studies have explored the relationship between neighborhood context and anthropometric outcomes among immigrants. Among those that have, the focus has generally been on foreign-born ethnic composition associations with health behaviors (40, 41, 78). Indeed a review by Papas, et al. highlighted the dearth of studies on the built environment and obesity in populations other than non-Hispanic Whites and African-Americans, and a lack of longitudinal studies in general (34).

Immigrants are a distinct social group from the native-born in that they express different cultural norms, perceptions, and motivations, and have different legal rights and

vulnerabilities (79). It remains unclear how neighborhood-level features may be relevant to health patterning for immigrants. Since the receiving context is an important determinant of successful adaptation of immigrants to the host country, it seems logical that health trajectories of immigrants would be related to environmental factors, but few studies have directly investigated this relationship.

Despite the growing independent literatures linking weight to neighborhood factors and acculturation processes, this literature has not considered the contingency of the relationships among acculturation, the neighborhood environment, and anthropometric measures. Moreover, it may be especially important to use longitudinal data to do so. Acculturation associations with weight could differ by neighborhood context/quality, for example, if neighborhoods facilitate preservation of certain beneficial behaviors over time among immigrants, thus preserving the weight advantage of immigrants compared to the U.S.-born. If this were the case, we would predict larger weight differentials by nativity in the best neighborhoods, and smaller differentials in the worst neighborhoods. Indeed, some literature suggests that an exposure that may have a small effect on a robust/healthy population, but may have a large effect on more vulnerable populations, such as immigrants (80, 81).

Using prospective data from Hispanic and Chinese participants in the Multi-Ethnic Study of Atherosclerosis (MESA), we investigated whether neighborhood residential environments characterized by greater availability of healthy food and better walkability modified the cross-sectional association between nativity/length of U.S. residence and baseline waist circumference (WC). We also examined whether these

neighborhood characteristics modified the longitudinal association between nativity/length of U.S. residence and change in WC over time.

Methods

MESA is a prospective study designed to investigate risk factors for subclinical cardiovascular diseases. Details on the design of MESA are provided elsewhere (28). In brief, participants aged 45-84 years without clinical cardiovascular disease at baseline were recruited from six study sites using a variety of population-based approaches (Baltimore, Maryland; Chicago, Illinois; Forsyth County, North Carolina; Los Angeles County, California; northern Manhattan, New York; and St. Paul, Minnesota). The MESA cohort includes 6814 individuals who self-identified as white, African American, Hispanic or Chinese-American. For this analysis, we included only Hispanic and Chinese participants because of the limited number of foreign-born individuals among the other race/ethnic groups. Hispanic participants were recruited from New York, Los Angeles, and St. Paul, and Chinese participants were recruited from Los Angeles and Chicago. We used data from the baseline examination (2000 and 2002), and three additional follow-up examinations approximately 18-24 months apart. All MESA participants provided written informed consent.

Waist circumference (WC) (cm) measurements were obtained at baseline and at each of the 3 follow-up visits using standardized procedures. For descriptive purposes, WC was also dichotomized based on the World Health Organization's criteria for 'high risk' of metabolic syndrome (56). Although we initially considered body mass index

(BMI) for this analysis, we focus our discussion on WC due to the decreased validity of BMI as a marker for adiposity among older individuals (82).

Nativity (U.S. vs. foreign birth) and years lived in the U.S. among the foreign-born were obtained during the baseline interview. We created a 5-level variable that combined nativity and length of U.S. residence as reported among the foreign-born (FB) at baseline: (FB < 15 years (referent); FB 15-30 years; FB > 30 years; FB missing years in U.S.; and U.S.-born).

Information on age (continuous, centered at the mean baseline age of 63), sex, race/ethnicity (Hispanic, Chinese), education (less than high school, high school diploma, some college/technical school, college graduate), and income (in 13 categories ranging from <$5,000 to $100,000+) was also obtained during the baseline interview. When missing, income data from follow-up exams was used to impute baseline income (1.7% of Hispanics; 0.62% Chinese). Participants selected their total family income within the past 12 months from 13 categories; a continuous measure of household-equivalized income was created by taking the midpoint for each category and dividing it by the number of household members. The variable was then categorized and expressed as quartiles of the sample distribution. Time since baseline, in years, was used to examine change in WC over time.

Participants were linked to their neighborhood of residence using their baseline home address. Information about the neighborhood built environment was obtained from questionnaires administered to MESA participants. In the survey, participants were asked about their agreement with items on a 5-point Likert scale (1=strongly agree; 5= strongly

disagree) in reference to items on neighborhood dimensions within a 1 mile (1.6 km) area surrounding their home. Scale items were derived from published work whenever possible (83, 84). Two scales were used in this analysis: availability of healthy food (2 items) and walking environment (6 items) (Table 3.1). Residents were asked, for example, the extent to which they agreed with the following statements: (1) A large selection of fruits and vegetables is available in my neighborhood, and (2) a large selection of low-fat products is available in my neighborhood. Scales were created by calculating the mean of the items included in the scale for all MESA participants, excluding the index case, living within a one mile radius of each MESA participant. Scores were reverse-coded so that higher scale scores indicated better resources. A summary physical environment score, combining walking environment and availability of healthy foods (the mean of the two scores), was also created.

We also adjusted for neighborhood socioeconomic status (SES) which has been previously shown to be correlated with neighborhood resources for diet and activity (85, 86), and also with adiposity (77, 87). Information on neighborhood socioeconomic characteristics was obtained from the 2000 U.S. Census. Census-defined block groups were used as proxies for neighborhoods. The variables used in the construction of the score were selected based on previously conducted factor analyses of census block group data (88). Six variables representing the dimensions of wealth/income, education, and occupation were combined into a summary neighborhood SES score; higher scores represented higher neighborhood SES.

Of the 1496 Hispanic and 803 Chinese MESA baseline participants, 180 Hispanics and 85 Chinese did not agree to provide information about their neighborhood environment. We further excluded 5 respondents for incomplete information on key covariates, resulting in a sample size of 1312 Hispanics and 717 Chinese participants. Of these 2029 baseline respondents, 85% of Hispanics and 87% of Chinese completed all follow-up examinations. Longitudinal analyses included all 2029 baseline participants regardless of completeness of follow-up.

Statistical analyses

All analyses were stratified by race/ethnicity (Hispanics and Chinese). We first classified the summary physical environment score into ethnicity-specific tertiles in order to compare means and frequencies across the tertiles. Ethnicity-specific tertiles were used because there were considerable differences between the groups in the distribution of the physical environment score. We estimated cross-sectional and longitudinal associations between nativity-length of U.S. residence and WC using linear mixed models with a random intercept and time slope for each individual (PROC MIXED SAS 9.2; SAS Institute Inc., Cary, NC). The first set of models included the nativity/length of U.S. residence variable, baseline age, sex, education, income, time since baseline, and time-by-age and time-by-nativity/length of U.S. residence interaction terms. The coefficient on the nativity/length of U.S. residence variable estimated its cross-sectional association with baseline WC. The coefficient on the time-by-nativity/length of U.S. residence term indicates how changes in WC over time varied by nativity/length of U.S. residence. We

also retained a time by sex interaction in Hispanic models because females experienced significantly greater increases in WC over follow-up time than males.

Having characterized the overall association between nativity/length of U.S. residence baseline WC and WC change over time, we next examined whether indicators of the neighborhood environment modified these associations. This was done by adding a 2-way interaction for nativity/length of U.S. residence-by-neighborhood scale term, and a 3-way interaction for nativity/length of U.S. residence-by-neighborhood scale-by-time. Scales for healthy food availability and walkability were investigated separately, and as a summary physical environment score. Each model was also adjusted for a continuous measure of neighborhood SES and its interaction with time. Since there was no evidence of non-linearity in the relationship between neighborhood indicators and WC, we examined them as continuous variables.

Estimates were standardized by ethnic group so that coefficients correspond to differences between the 90^{th} and 10^{th} percentiles of each indicator (translating to differences of 0.90 for Hispanics and 0.57 for Chinese for the healthy food availability scale; 0.61 for Hispanics and 0.53 for Chinese for the walkability scale; and 0.61 for Hispanics and 0.41 for Chinese for the physical environment scale). Inclusion of a random intercept for each census tract did not alter estimates so we report results from simpler models. Likelihood ratio tests were used to determine the joint significance of the set of interaction terms for a given neighborhood measure. In sensitivity analyses, we also examined whether results differed based on whether participants moved from their baseline address.

Results

Overall, the Hispanic sample was of lower SES than the Chinese sample (Table 3.2). A considerably larger proportion of Chinese compared to Hispanics were foreign-born. Mean scores for all neighborhood scales characterizing the physical environment were similar for both groups however Hispanics resided in areas marked by lower SES. Hispanics participants had a higher mean WC at all exams and a greater increase in mean WC compared to Chinese participants. Over a median follow-up of 5 years, both Hispanics and Chinese experienced increases in WC over time though the magnitude was slightly larger for Hispanics.

Compared to their U.S.-born counterparts, Hispanic foreign-born individuals were of lower SES, and were more likely to live in neighborhoods with lower area-level SES (Table 3.2). However foreign-born Hispanics also lived in neighborhoods with better resources for healthy food. They also had a lower mean WC at all exams, a lower baseline prevalence of high-risk WC, but slightly greater increases in WC over time than U.S.-born Hispanics.

Compared to U.S.-born Chinese-Americans, Chinese foreign-born participants were also of lower SES, and lived in neighborhoods with lower area-level SES (Table 3.2). They also resided in neighborhoods with lower mean scores on all physical environment indicators. Foreign-born participants nevertheless had a lower mean WC at all exams than the U.S.-born, but had a greater mean increase in WC over follow-up.

Table 3.3 presents the distribution of sample characteristics by tertiles of the summary score characterizing the physical environment. Among Hispanics, individuals

with a higher individual-level SES were more likely to live in neighborhoods with better healthy food availability and walkability. Better neighborhoods also had a higher proportion of foreign-born individuals, and a higher proportion of more long-term immigrants. There was no clear relationship between neighborhood-level SES and the physical environment score. Mean baseline WC and mean WC change were highest in the lowest tertile.

Among Chinese, although a slightly greater proportion of higher SES individuals lived in neighborhoods characterized by a higher physical environment score, the SES distribution across tertiles was much less disparate than it was for Hispanics. Better neighborhoods also had more long-term immigrants and were associated with a higher area-level SES. Similar to Hispanics, mean baseline WC and mean WC change were highest in the lowest tertile.

Table 3.4 shows adjusted mean differences at baseline and mean difference in annual change in WC by nativity-length of U.S. residence for Hispanics and Chinese. Among Hispanics, after adjusting for individual-level demographic and socioeconomic characteristics, there was no significant difference in baseline WC with increasing length of U.S. residence; U.S.-born participants however had a mean baseline WC over 5 cm higher compared to immigrants in the U.S. < 15 years ($\beta = 5.06$ cm, $p=0.0004$). Although mean WC increased over follow-up for all Hispanics (data not shown), increases among the U.S.-born were marginally lower than for immigrants in the U.S. < 15 years.

Similar to Hispanics, Chinese immigrants showed no substantial differences in mean baseline WC, regardless of how long they had lived in the U.S. However, the U.S.-

born had nearly 4 cm higher baseline mean WC than the most recent immigrants (β = 3.97 cm, p=0.04). All Chinese participants experienced increases in WC over follow-up (data not shown), but immigrants in the U.S. > 30 years had a significantly lower increase than immigrants in the U.S. < 15 years (β = -0.30 cm/year, p=0.009).

Next, we examined whether neighborhood environments modified the cross-sectional and longitudinal relationship between nativity/length of U.S. residence and baseline WC, and change in WC. We enrich the Hispanic and Chinese models from table 4 by adding the neighborhood score variables, and interaction terms for neighborhood-by-nativity/length of U.S. residence, neighborhood-by-time, and neighborhood-by-nativity/length of U.S. residence-by-time. To ease interpretation, we represent all results graphically in figures 3.1 and 3.2.

Among Hispanics, heterogeneity by neighborhood environment in the cross-sectional relationship between nativity/length of U.S. residence and WC was suggestive but not statistically significant among Hispanics when examining differences by healthy food availability (p-interaction = 0.1) and by the summary score for physical environment (p-interaction = 0.09) (no heterogeneity was evident using the walkability scale). We aggregated all Hispanic immigrants into one group, since results (not shown) implied that patterns among immigrants were similar regardless of length of residence. The mean difference in baseline WC between the foreign-born and U.S.-born was larger in neighborhoods with higher (90^{th} percentile score, solid lines) than with lower (10^{th} percentile, dashed lines) healthy food availability (Figure 3.1). Analogously, greater healthy food availability was associated with lower WC in the foreign-born but not in the

U.S.-born. Trends over time in WC were similar regardless of neighborhood characteristics, i.e. none of the neighborhood indicators modified the relationship between nativity/length of U.S. residence and change in WC. There was no evidence of modification cross-sectionally or longitudinally when examining walkability of the neighborhood environment.

Among the Chinese, we restricted tests for heterogeneity to the foreign-born due to the small sample size of the U.S.-born. We found significant heterogeneity, specifically when examining differences in the relationship between length of U.S. residence and change in WC over time using the walkability scale (p-interaction = 0.04) (Figure 3.2). There was no difference in WC change by baseline length of U.S. residence in neighborhoods with better walkability (90^{th} percentile, solid lines). By contrast, in the least walkable neighborhoods, more recent immigrants had a more rapid rate of WC increase over time than more long-term immigrants (10^{th} percentile, dashed lines). Consequently, by the end of available follow-up, the WC estimates of these more recent immigrants surpassed estimates among more long-term immigrants. There was no evidence of modification cross-sectionally or longitudinally when examining availability of healthy food.

Restricting analyses to participants that did not move from their baseline address did not alter estimates from interaction models for either Hispanics or Chinese.

Discussion

Using prospective data from MESA, we investigated whether features of the neighborhood physical environment modified the association of nativity/length of U.S.

residence on baseline WC and on change in WC. Our results suggest that where immigrants live may have implications for the weight-related patterns that emerge for this group. Among Hispanics, there was a larger mean difference in baseline WC by nativity in environments with greater availability of healthy food. Among Chinese participants, the walkability of the environment modified the longitudinal relationship between length of U.S. residence and WC change, such that the impact of more years in the U.S. on greater WC change was weaker in more walkable neighborhoods. Moreover, different features of the neighborhood appeared to have distinct implications for WC for Hispanics and Chinese.

Hispanics

Although not statistically significant, our results suggested the presence of heterogeneity in the cross-sectional association between nativity and WC. Greater healthy food availability was associated with a lower baseline WC among foreign-born participants, but not among the U.S.-born. The presence of a larger nativity gradient in 'better' neighborhoods may appear counterintuitive because one would expect WC estimates among the U.S.-born to also be lower in better quality neighborhoods. Few studies have examined whether contextual factors have a differential association with health by nativity. One study that investigated variation by neighborhood linguistic isolation in the relationship between nativity and BMI found that U.S.-born Hispanics had a higher BMI in areas of low linguistic isolation. However there were no BMI differences among the foreign-born (19). Another study that linked residence in an

immigrant enclave to birthweight among Mexican-Americans also found contextual factors to be more associated among the U.S.-born, but not the foreign-born (89).

The reasons underlying our findings remain unclear, but we can speculate on the dynamics that may have given rise to this patterning. Assuming a casual relationship between the neighborhood and WC, this finding may point to greater susceptibility among foreign-born Hispanics to their physical environment. This may be inconsistent with the few findings available in the literature; however the contextual variables used in previous studies are likely to have a more complex relationship with health. The neighborhood indicators we examined may be more directly relevant for WC. Availability of healthy food may exert a greater influence on immigrants if they spend more time in their residential neighborhoods and/or if they rely to a great extent on the dietary resources there. However, residual confounding and selection effects may also be operating which could complicate interpretation of these findings. For example, selection processes that may be occurring to a greater extent among the foreign-born than the U.S.-born could also contribute the pattern we observed. Additional research will be necessary to uncover the nature of these dynamics.

Chinese

Compared to Hispanics, much less is known about the health patterning of Chinese immigrants. This study offers insight on this relatively unexplored group which has origins in one of the top immigrant sending countries to the U.S. (57). In highly walkable neighborhoods, there was little difference in WC change by length of U.S.

residence; however in areas of poor walkability, there was a greater rate of WC increase among newer immigrants compared to long-term immigrants.

The few studies that have examined weight-related patterning by nativity or length of residence among Chinese-Americans have been cross-sectional and results are mixed (19, 20, 26). Although we demonstrated little difference in baseline WC by length of the U.S. residence, rates of WC change differed across immigrant cohorts depending on where they lived. This finding underscores the importance of using longitudinal data to investigate immigrant health patterns that emerge with longer time in the U.S. We found a non-significant but positive relationship between length of U.S. residence and WC at baseline, but at the end of follow-up, more recent immigrants had a higher WC than more long-term immigrants in neighborhoods with poor walkability. This suggests that drawing conclusions based on a cross-sectional approach can yield different patterns at different time points. Moreover, failing to account for the environmental factors that may be relevant for shaping immigrant health trajectories is apt to produce an incomplete picture.

The underlying reasons for why newer immigrants experienced greater WC increases than long-term immigrants in neighborhoods with poor walkability are likely to be complex. More recent immigrants may be more vulnerable to the influences of their new environment. Methodological factors may have also played a role. Although our findings were robust to analyses that were restricted to non-movers, we note that Chinese immigrants in MESA were a highly mobile group. Factors that drive selection and residence in certain types of neighborhoods, as well as movement away from these

neighborhoods will require further investigation to evaluate their underlying influence on immigrant health patterns.

Limitations and Strengths

Some additional limitations should be noted in interpreting the results of this study. We only had a relatively short time frame for examining change in WC. Since central obesity tends to develop over a long period of time and may be influenced by exposures in early life and over the life course, this may preclude the ability to detect significant changes in waist size over time. However for this reason, it is noteworthy that we found any WC change in the Chinese sample. Some analyses may have also been constrained by sample size. Our sample of U.S.-born Chinese was small. Moreover, we recognize that sub-analyses by gender and Hispanic subgroups are important in research of immigrants, but power limited our ability to account for variation in these factors. The older age and health-selected nature of MESA sample may also limit generalizability of our findings to other groups.

Despite these limitations, our study addressed gaps in the literature by examining immigrant health patterns from a longitudinal perspective. Another advantage of this work is the use of clinically-measured WC, a strong marker of metabolically active visceral adiposity and a known risk factor for CVD (54, 55). Most studies of immigrants rely on self-reported information which may be subject to bias. The availability of more detailed measures of the built environment also permitted a more thorough investigation of the residential context in which immigrants reside. Studies that examine the environmental factors that are thought to shape immigrant health are sparse, and have

relied on more global measures of the neighborhood such as area SES or immigrant concentration.

Implications and Future Directions

The erosion of health that accompanies greater acculturation to U.S. society has been hypothesized to operate through environmental factors that compel adoption of negative health behaviors among immigrants. Our results suggest that features of the neighborhood environment may have implications on WC measurements for Hispanic and Chinese immigrants in MESA. If immigrants, especially more recent arrivals, are indeed more susceptible to weight gain in response to adverse conditions of the physical environment, interventions aimed at arresting health deterioration may require a more targeted approach in communities where immigrants reside.

Our results also suggest that certain features of the neighborhood have different implications for WC depending on the ethnic group under study. Resources that support healthy eating were more relevant for Hispanics and walkability was more relevant for the Chinese. A recent review by Lovasi et al highlighted the presence of race/ethnic variation in the association between various indicators of the built environment and obesity prevalence (90). Neighborhood-level interventions aimed at promoting health behaviors that reduce obesity will need to be sensitive to the modifiable features of the environment that may be more relevant for certain communities.

We relied on survey-based measures of the environment to characterize the neighborhood physical environment. However, there may be additional aspects of the environment better captured by other structural measures. Several studies have shown the

presence of supermarkets and recreational facilities, for example, to be health-promoting (37, 75, 91). Future research will be necessary to examine whether these characteristics have any bearing on immigrant health patterning.

Table 3.1. MESA Questionnaire Items for Neighborhood Scales				
Scale	Number of items	Scale internal consistency reliability (Cronbach's alpha)	Items	Rating scale for each item
Healthy Food Availability Scale	2	0.90	(1) A large selection of fresh fruit and vegetables is available in my neighborhood; (2) A large selection of low-fat products is available in my neighborhood	1=strongly disagree to 5= strongly agree
Walking Environment Scale	6	0.61	(1) It is pleasant to walk in my neighborhood; (2) The trees in my neighborhood provide enough shade; (3) In my neighborhood it is easy to walk to places; (4) I often see other people walking in my neighborhood; (5) I often see other people exercise in my neighborhood; (6) There are stores within walking distance of my home	1=strongly disagree to 5= strongly agree

Table 3.2. Distribution of Sample Characteristics, Hispanics and Chinese, Multi-Ethnic Study of Atherosclerosis

	HISPANICS			CHINESE		
	Sample	**U.S. born**	**Foreign-born**	**Sample**	**U.S. born**	**Foreign-born**
N	1312	429	883	717	29	688
Mean age, baseline (SD)	61.2 (10.3)	61.6 (10.4)	61.1 (10.2)	61.8 (10.2)	60.6 (9.8)	61.8 (10.2)
% Female	51.9	46.9	54.4	50.8	41.4	51.2
Education (%)						
Less than high school	43.1	19.6	54.6	22.3	3.5	23.1
Completed high school/ GED	21.1	28.2	17.7	16.3	17.2	16.3
Some college/technical school	25.6	39.4	18.9	20.8	13.8	21.1
Bachelor's/graduate degree	10.1	12.8	8.8	40.6	65.5	39.5
Income quartiles, US $ (%) †						
0	26.7	11.4	34.2	25.9	3.5	26.9
1	27.1	19.1	30.9	29.9	13.8	30.5
2	21.7	29.1	18	14.5	17.2	14.4
3	24.5	40.3	16.9	29.7	65.5	28.2
% Foreign-born	67.3	-	-	96	-	-
Years lived in U.S., baseline (%)						
< 15 years	14	-	14	35	-	35
15-30 years	24.7	-	24.7	38.8	-	38.8
>30 years	49.8	-	49.8	19.6	-	19.6
Missing	11.4	-	11.4	6.5	-	6.5
Neighborhood information						
Mean years lived in neighborhood (SD)	18.8 (14)	23.6 (16)	16.5 (12.4)	11 (9.7)	28.8 (19.4)	10.2 (8.3)
% Moved from baseline address	24.6	24.9	24.5	34	3.2	34.7
Mean Walkability score (SD)	3.81 (0.23)	3.79 (0.23)	3.81 (0.22)	3.76 (0.24)	3.94 (0.36)	3.75 (0.24)
Mean healthy food availability score (SD)	3.61 (0.40)	3.46 (0.44)	3.68 (0.36)	3.66 (0.27)	3.74 (0.43)	3.66 (0.26)
Mean physical environment score (SD)	3.71 (0.27)	3.63 (0.27)	3.75 (0.25)	3.71 (0.22)	3.84 (0.37)	3.71 (0.21)
Mean neighborhood socioeconomic	-2.94 (4.9)	-1.22 (4.5)	-3.78 (4.8)	0.93 (5.1)	1.60 (4.8)	0.90 (5.2)

score (SD)						
Mean waist circumference (cm) (SD)						
Baseline	100.7 (13.1)	103.2 (14.5)	99.5 (12.2)	87.2 (9.9)	90.8 (14.7)	87.0 (9.6)
First follow-up	100.9 (13.5)	103.1 (15.2)	99.8 (12.5)	87 (9.7)	90.4 (14.7)	86.8 (9.4)
Second follow-up	101.5 (13.5)	104.1 (14.9)	100.3 (12.6)	87.2 (9.9)	90.1 (15.1)	87.1 (9.6)
Third follow-up	102.3 (13.8)	104.4 (15.2)	101.3 (13.0)	88.3 (9.7)	90.6 (13.3)	88.2 (9.6)
Mean 5-year change WC (SD)	1.6 (6.5)	1.1 (6.6)	1.8 (6.4)	1.2 (5.2)	0.47 (5.8)	1.2 (5.2)
High risk waist circumference, baseline (%)*						
Men: >=102 cm	41.2	47.8	37.5	7.7	17.7	7.1
Women: >=88 cm	81.1	82.6	80.4	40.7	50	40.3

*Based on the World Health Organization's sex-specific cutoffs for waist circumference measurements at high risk for metabolic syndrome
†Continuous measure of income adjusted for household size, expressed as quartiles

Table 3.3. Distribution of Sample Characteristics by Tertiles of Neighborhood Physical Environment Score, Hispanics and Chinese, Multi-Ethnic Study of Atherosclerosis

	HISPANICS			CHINESE		
	Neighborhood healthy food availability and walkability, summary score			Neighborhood healthy food availability and walkability, summary score		
	Worst	**Intermediate**	**Best**	**Worst**	**Intermediate**	**Best**
N	434	427	451	235	238	244
Mean age, baseline (SD)	60.2 (10.0)	62.9 (10.4)	60.6 (10.2)	61.4 (10.1)	62.1 (10.7)	61.9 (9.8)
% Female	50.2	54.1	51.4	49.4	47.9	54.9
Education (%)						
Less than high school	46.5	48.5	34.8	27.7	18.5	20.9
Completed high school/ GED	21.7	19.2	22.4	18.3	14.7	16
Some college/technical school	24	24.6	28.2	20.4	20.6	21.3
Bachelor's/graduate degree	7.8	7.7	14.6	33.6	46.2	41.8
Income quartiles, US $ (%) †						
0	32	28.1	20.4	27.7	23.5	26.6
1	25.8	29	26.4	33.2	34	22.5
2	20.5	22	22.4	13.2	16.8	13.5
3	21.7	20.8	30.8	26	25.6	37.3
% Foreign-born	56.2	63.9	81.2	97	96.6	94.3
Years lived in U.S., baseline (%)						
< 15 years	20.1	14.3	9.8	36.4	40.4	28.3
15-30 years	27.9	26.7	21	43.9	37	35.7
>30 years	37.7	50.6	57.4	14.5	14.4	30
Missing	14.3	8.4	11.8	5.3	8.3	6.1
Neighborhood information						
Mean years lived in neighborhood (SD)	16.9 (15.3)	18.5 (13.8)	20.9 (12.7)	10.4 (9.3)	9.2 (6.8)	13.4 (11.9)
% Moved from baseline address	27.9	25.8	20.4	39.1	33.6	29.5
Mean Walkability score (SD)	3.67 (0.17)	3.73 (0.15)	4.01 (0.19)	3.56 (0.15)	3.73 (0.14)	3.99 (0.21)
Mean healthy food availability score (SD)	3.18 (0.33)	3.66 (0.16)	3.96 (0.20)	3.45 (0.27)	3.70 (0.14)	3.83 (0.23)
Mean neighborhood socioeconomic score (SD)	-2.74 (3.9)	-4.01 (4.6)	-2.12 (5.7)	-0.70 (4.8)	1.57 (5.0)	1.88 (5.2)

Mean waist circumference (cm) (SD)						
Baseline	102.3 (13.4)	100.4 (12.5)	99.4 (13.4)	88.8 (9.2)	86.9 (10.3)	86.7 (10.2)
First follow-up	103.1 (13.8)	100.0 (13.2)	99.6 (13.3)	87.6 (9.0)	86.7 (10.1)	86.5 (10.0)
Second follow-up	104.3 (13.7)	100.6 (13.1)	99.8 (13.3)	88.3 (9.4)	87.1 (9.9)	86.3 (10.2)
Third follow-up	104.6 (14.4)	101.4 (12.9)	101.1 (13.9)	89.6 (9.4)	88.3 (9.9)	87.0 (9.8)
Mean 5-year change WC (SD)	1.97 (6.6)	0.96 (6.5)	1.71 (6.4)	1.7 (5.2)	1.5 (5.3)	0.49 (5.1)
High risk waist circumference, baseline (%)*						
Men: >=102 cm	44.9	37.2	41.1	9.2	8.1	5.5
Women: >=88 cm	85.8	82.7	75	42.2	39.5	40.3

*Based on the World Health Organization's sex-specific cutoffs for waist circumference measurements at high risk for metabolic syndrome
†Continuous measure of income adjusted for household size, expressed as quartiles

Table 3.4. Adjusted Mean Difference at Baseline and Mean Difference in Annual Change in Waist Circumference (cm) by Nativity/Length of U.S. Residence, Hispanics and Chinese

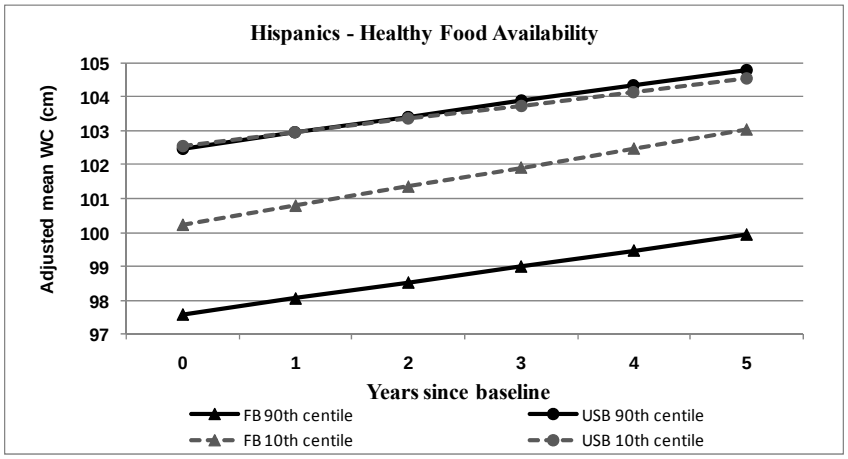
	HISPANICS[†]		CHINESE[‡]	
	Mean difference at baseline	Mean difference in annual change	Mean difference at baseline	Mean difference in annual change
Nativity-length of U.S. residence				
< 15 years U.S.	Ref	Ref	Ref	Ref
15-30 years	0.29 (1.47)	-0.19 (0.15)	0.36 (0.87)	-0.05 (0.09)
>30 years U.S.	1.17 (1.38)	-0.20 (0.14)	0.84 (1.10)	**-0.30 (0.11)*** **
Missing	1.47 (1.76)	-0.28 (0.18)	0.50 (1.58)	0.12 (0.17)
U.S.-born	**5.06 (1.44)*** **	-0.27 (0.14)*	**3.97 (1.93)** **	-0.26 (0.21)

****P<0.0001; ***P<0.01, **p<0.05, *P<0.1

[†]Model further adjusted for age, sex, education, income, time since baseline, age*time, sex*time

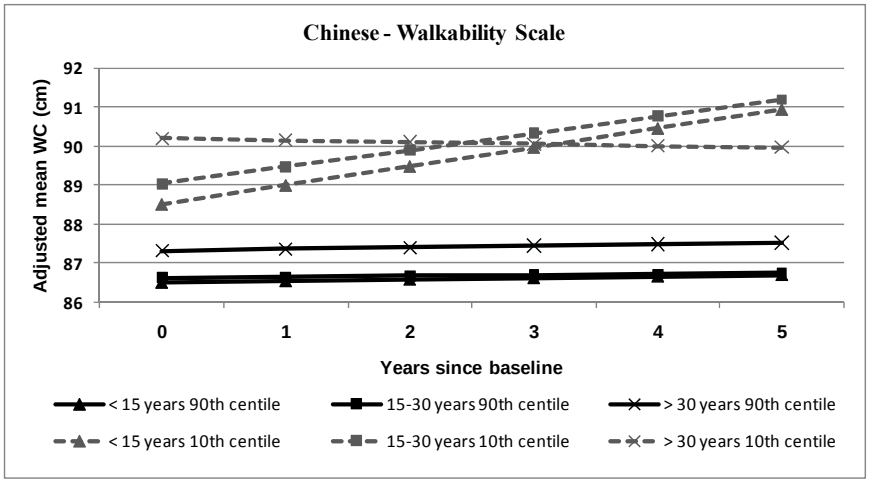
[‡]Model further adjusted for age, sex, education, income, time since baseline, and age*time

Figure 3.1. Adjusted mean waist circumference trajectories over time by nativity, at the 90th vs. 10th percentile of healthy food availability – Hispanics



WC=waist circumference. All models further adjusted for age, sex, education, income, age*time, neighborhood socioeconomic status (SES) score and neighborhood SES score*time. Estimates shown were calculated to correspond to the mean age of the entire sample (age=63). P-interaction (nativity*healthy food availability) = 0.1.

Figure 3.2. Adjusted mean waist circumference trajectories over time by baseline length of U.S. residence among the foreign-born – Chinese



WC=waist circumference. All models further adjusted for age, sex, education, income, age*time, neighborhood socioeconomic status (SES) score and neighborhood SES score*time. Estimates shown were calculated to correspond to the mean age of the entire sample (age=63). Foreign-born with missing data on baseline length of U.S. residence included in interaction model but not plotted in figure. P-interaction (length of residence*walkability*time) = 0.04.

Chapter 4

Secular trends in adiposity and body mass index by nativity and length of U.S. residence among Mexican-Americans, 1988-2008

Introduction

The U.S. has experienced alarming growth in overweight and obesity over the past few decades impacting all segments of society irrespective of race, sex, and socioeconomic status (SES) (92, 93). Between the 1960s and 2004, obesity prevalence in the U.S. rose from 13% to 32%. By 2015, 75% of adults are projected to be overweight or obese, 41% of which will be obese (93). The epidemic has enormous implications for mortality, morbidity, healthcare costs and quality of life across all ages (94).

Although the obesity epidemic has affected all socio-demographic groups, race/ethnic disparities have been extensively documented. Hispanics, especially those of Mexican-origin who represent the largest Hispanic subgroup in the U.S., are characterized by obesity rates only slightly less than those of African-Americans and considerably higher than those of whites (95). According to reports based on data from the National Health and Nutrition Examination Survey (NHANES), between 1999-2000 and 2007-2008, the prevalence of obesity among Mexican-Americans rose from 28.9% to 35.9% for men, and from 39.7% to 45.1% for women (95). Although Hispanics in the U.S. are disproportionately affected by obesity relative to whites, there is evidence of important heterogeneity within this group. Foreign-born Hispanics are characterized by a

lower body mass index (BMI) compared to the native-born population, despite low socioeconomic status (SES) (21, 44). Behavioral change and contextual factors associated with longer length of U.S. residence have been associated with the development of obesity among immigrants (16, 43). However since most studies examining nativity differences in weight have been conducted at a single point in time, it remains unclear whether this relationship has varied over time. Furthermore, although nationally representative data from NHANES has documented an increase in obesity among Mexican-Americans, variation in these trends by place of birth has not been investigated. Since immigrants account for approximately 38% of all Hispanics in the U.S. (58), examination of weight-related trends by nativity may uncover an important source of heterogeneity. The focus on Mexican-American adults permits quantification of these relationships specifically among the largest immigrant group in the U.S., and the largest ethnic subgroup among Hispanics (57, 58).

A number of factors could lead to variation in the relationship between measures of acculturation (i.e. nativity and years lived in the U.S.) and weight by calendar time. In light of obesity trends occurring at a global level, more recent waves of immigrants may be arriving with higher BMI than previous waves of immigrants. Mexico in particular, the largest immigrant sending-country to the U.S., has been confronted by an obesity epidemic that rivals that of the U.S. (31). Changes over time to factors associated with the acculturation process, and with the political, economic, and social environment of receiving communities may also alter the impact of longer length of U.S. residence on weight gain among immigrants. Identifying how acculturation is related to BMI among

Mexican-Americans and how these relationships may have changed over time is fundamental to understanding the causes of the obesity epidemic in this group and to the development of more effective strategies for prevention.

Using nationally representative data on Mexican-American adults spanning a 20-year period, we explored trends in BMI, waist circumference (WC), and the prevalence of obesity by nativity and length of U.S. residence. We also investigated whether the relationship between nativity/length of U.S. residence and BMI and WC varied by calendar time.

Methods

Study population and variables

We used data from successive waves of the third National Health and Nutrition Survey (NHANES) III (1988-1994), and the continuous NHANES (1999-2008)(96). NHANES is a series of cross-sectional nationally representative health examination surveys beginning in 1960. In each survey, a nationally representative sample of the U.S. civilian non-institutionalized population was selected using a complex, stratified multi-stage probability cluster sampling design. Oversampling of Mexican-Americans did not begin until NHANES III precluding the use of data from earlier surveys. NHANES III was conducted between 1988 and 1994, and the sample was designed so that the entire six years was a national probability sample. Beginning in 1999, NHANES became a continuous survey, in which approximately 5,000 individuals of all ages completed the health examination component of the survey each year. The continuous surveys, which are a series of repeated cross-sections, are available in two-year blocks (i.e. 1999-2000,

2001-2002, 2003-2004, etc). All these surveys oversampled Mexican-Americans to produce statistically reliable estimates for this subgroup. There were two phases of data collection: in the first phase, researchers collected information from household interviews on demographics, socioeconomic indicators, past medical history, and health behaviors. In the second phase, participants were administered a physical examination in a mobile examination center, which included the collection of blood and urine specimens for laboratory testing.

In order to achieve sufficient sample sizes, we pooled NHANES data to represent three calendar time points: 1988-1994 (NHANES III), 1999-2004 (continuous NHANES), and 2005-2008 (continuous NHANES). We restricted the sample to adult, non-pregnant women and men aged 20-64 who self-identified as Mexican/Mexican-American. The sample was limited to adults less than 64 years of age to avoid selection problems that may arise from morbidity/mortality associated with older age, as well as to allow for a more interpretable examination of change in BMI that is less likely to be influenced by age-related loss of body mass (82, 97). Of the 4614 men (1988-1994: n=1898; 1999-2004: n=1674; 2005-2008: n=1042) and 4199 women (1988-1994: n=1795; 1999-2004: n=1458; 2005-2008: n=946) that met our inclusion criteria, we further excluded individuals with missing information on BMI and other key covariates of interest (men: 8.2% missing; women: 6.8% missing), yielding a final sample of 4235 men and 3914 women for analyses examining BMI. Waist circumference models included a sub-sample of 4129 men and 3808 women among whom this information was available.

All height (m) and weight (kg), and waist circumference (cm) measurements were obtained via physical examination. Body mass index (BMI) (kg/m^2) and waist circumference (WC) were examined as separate outcomes and as continuous variables. For descriptive purposes, participants were also classified based on the World Health Organization's (WHO) criteria for levels of WC deemed to be at 'high risk' for metabolic syndrome (men: $\geq$ 102 cm; women $\geq$ 88 cm) (56). Obesity prevalence (BMI $\geq$ 30 kg/m^2) was also modeled. Information on nativity (U.S. vs. foreign-birth), years lived in the U.S. among the foreign-born, age, sex, and education (less than high school education, completed high school, and more than high school) were obtained via self-report during the household interview. We also created a single 3-level variable to examine nativity and length of U.S. residence together: U.S.-born represented the referent group and length of U.S. residence was categorized as < 10 years and $\geq$ 10 years to characterize the foreign-born.

Statistical Analysis

All results were stratified by sex. Appropriate sampling weights were incorporated to produce national population estimates for Mexican-Americans for each calendar period. Sampling weights accounted for unequal probabilities of selection, non-response, and non-coverage. All analyses were conducted using SAS version 9.2 (SAS Institute Inc., Cary, NC) and SUDAAN version 10.01 (RTI, Research Triangle Park, NC) with Taylor series linearization methods to adjust for the complex survey design. Age-adjusted means (BMI and WC) and prevalence (obesity) were first calculated and plotted for each level of the nativity/length of U.S. residence variable both within and across

survey periods. As a point of reference, estimates for whites were also plotted. To facilitate comparisons, estimates were age-adjusted by the direct method to the 2000 U.S. standard population (98). Differences across nativity categories, length of U.S. residence and survey years were evaluated using the t-statistic, and a p-value of <0.05 was considered significant. Multivariable linear regression was then used to separately model the association between the nativity/length of U.S. residence variable ($<$ 10 years U.S., $\geq$ 10 years U.S., U.S.-born (ref)), and continuous measures of BMI and WC among Mexican-Americans, controlling for continuous age and NHANES survey period (1988-1994 (ref), 1999-2004, 2005-2008). An age-squared term was also retained in models in which age had a non-linear relationship with BMI and WC (all except WC models among women). An age by period interaction was also included since the association between age and all anthropometric measures was not constant over time. Subsequent models controlled for education (less than high school (ref), completed high school, more than high school). To investigate whether the relationship between nativity/length of U.S. residence and BMI/WC varied by time, models included an interaction between the nativity/length of residence variable and NHANES period. We also considered whether variation by calendar time in the relationship between nativity/length of residence and BMI/WC differed by level of educational attainment. Multivariable logistic regression was similarly used to estimate odds ratios for obesity however since results were similar to those obtained examining BMI and WC, these results are not shown.

Results

Sample characteristics for Mexican-American men and women by nativity and for each of the periods under study are presented in Table 1. Across all periods, foreign-born Mexican men and women were more likely than U.S.-born Mexicans to have less than a high school education. However the educational distribution among all Mexican-Americans shifted towards higher educational attainment with increasing calendar time. Among men, the foreign-born consistently had a lower mean BMI and WC, and a lower prevalence of obesity and high-risk WC than the U.S.-born. In contrast among women, except for mean WC in 2005-2008, there were no statistically significant differences by nativity in any of the anthropometric measures investigated regardless of survey year.

Among men, BMI, WC, obesity, and high-risk WC were higher in 2005-2008 than in 1988-1994, in both the U.S. and foreign-born, though the increase in high-risk WC among the foreign-born was not statistically significant. Among foreign-born women, mean estimates suggested higher levels of all anthropometric measures in 2005-2008 than in 1988-1994, but only the difference in WC was statistically significant. Among U.S.-born women, all anthropometric measures, except BMI, were significantly higher over time.

Figure 1 (A-F) illustrates the age-adjusted mean BMI, mean WC, and obesity prevalence across NHANES survey periods by nativity and length of U.S. residence among Mexican-Americans and whites for men and women. Among men, the highest BMIs were observed among U.S.-born Mexican-Americans, whereas the lowest BMIs were observed for immigrants in the U.S. < 10 years (Fig. 1A). Intermediate and similar levels were observed for immigrants in the U.S. ≥ 10 years and for whites. These patterns

generally held across calendar time and were also present for WC (Fig. 1B) and obesity prevalence (Fig. 1C).

In contrast to the patterns found among men, all Mexican-American women, regardless of nativity and length of residence, had higher BMIs than white women (Fig. 1D). In general, there was little difference in BMI among the three Mexican-American groups. Similar patterns were observed for WC (Fig. 1E) and obesity prevalence (Fig. 1F).

Table 2 presents adjusted mean differences in BMI and WC by nativity/length of U.S. residence stratified by period (top panel), and by period stratified by nativity/length of U.S. residence (bottom panel) among Mexican-Americans. Estimates were derived from a model including nativity/length of U.S. residence, age, age^2, NHANES survey period, and interactions between age and period, and between nativity/length of U.S. residence and period (Model 1). Model 2 adjusts for education. All foreign-born men had a lower mean BMI and WC than U.S.-born men across all years. There was a graded relation by which the lowest BMI and WC estimates were observed among foreign-born men in the U.S. < 10 years followed by those in the U.S. ≥ 10 years (Model 1, top panel). All men experienced increases in BMI and WC over time, although changes over time were of a small magnitude and not statistically significant among recent immigrants (Model 1, bottom panel). However tests for the interaction between nativity/length of U.S. residence and NHANES period were not statistically significant (P for additive interaction = 0.3 (BMI model); p=0.5 (WC model)). Adjusting for education did not appreciably alter estimates (Model 2, top panel). Education was not associated with BMI

among men, but having more than high school education was associated with a lower WC.

Among women, foreign-born women tended to have lower BMI and WC than US born women, but these differences were substantial and statistically significant only after adjustment for education (Models 1 and 2, top panel). There were no substantial differences between immigrants in the US < 10 years or ≥10 years. Similar patterns were observed across calendar periods. BMI and WC tended to increase over time in all groups but differences in BMI were small and less likely to be statistically significant than differences in WC. (Model 1, bottom panel). There was no evidence of an additive interaction between nativity/length of U.S. residence and NHANES period in either BMI or WC models. Having more than high school education was associated with a lower BMI and WC (Model 2).

We also considered whether variation in the relationship between nativity/length of U.S. residence and BMI/WC by calendar time was further modified by educational attainment (less than high school; high school or more). Since trajectories over time were similar among individuals who completed high school and those with more than high school, we collapsed this category into 'high school or more' to ease interpretation and improve stability of the estimates. The original patterns among men were not altered. However among women, period differences in the relationship between nativity/length of U.S. residence and BMI or WC varied by educational attainment (3-way interaction between nativity/length of U.S. residence*education*survey period: p (BMI model) = 0.0114; p (WC model) = 0.05). Since results were similar across all anthropometric

outcomes, we present results only for BMI. Adjusted mean estimates were computed from the interaction model and plotted in Figure 2.

Among Mexican-American women with less than high school education, BMI differences by nativity and length of residence became magnified over time: in 1988-1994 there was little difference in BMI across the 3 groups, but by 2005-2008, the U.S.-born had a considerably higher BMI than either of the foreign-born groups. This gap was attributable to large increases in BMI among U.S.-born women with less than high school education, and little increase in BMI over time among similarly educated foreign-born women. Among women with high school or more education, the U.S.-born had a higher BMI than both foreign-born groups in 1988-1994, but by 2005-2008, nativity differences were minimized due to little change in BMI among the U.S.-born paired with marked increases in BMI over time among both foreign-born groups.

Discussion

We used a nationally representative sample to describe 20-year trends in anthropometric outcomes for Mexican-Americans. We characterized differences in these outcomes between immigrants and the U.S. born, and between more recent and less recent immigrants, and explored how these patterns have changed over the past two decades. We noted important differences in these patterns between men and women. Taken together, our results enrich the picture that has been emerging in the literature on immigrant health and race/ethnic health disparities.

Among men, we documented a gradient consistent with patterns described elsewhere in the literature (7, 18, 21, 22, 44, 66, 67). BMI and WC were highest among

the U.S. born, somewhat lower among long-term immigrants, and lowest among the most recent immigrants. Hypotheses to explain this pattern have focused on selective migration and protective cultural characteristics among newer immigrants. Migrants are thought to be younger and healthier relative to their native populations, and are thus selected for their ability to better cope with the rigors of the migration process (3). To explain the later decline associated with longer time in the U.S., hypotheses have focused on the concept of acculturation, defined as a process whereby immigrants over time come to adopt the behaviors and norms of their new culture. This deterioration in health linked to the process of acculturation is thought to be related to the acquisition of negative risk factors, such as poorer diet, a more sedentary lifestyle, and increases in smoking and alcohol intake after leaving the country of origin (7, 11).

We contribute to this picture in several ways. First, we differentiate patterns among women from those among men. Many studies examining these patterns have pooled results across sexes. Those that have differentiated by sex have reported differences between men and women consistent with our findings (7, 16, 18, 21, 45, 66). Using National Health Interview Survey (NHIS) data from 1989-1996, Antecol et al, for example, reported smaller nativity differentials in self-reported BMI among females than males across races (21). However, our analysis illustrates that once differences in educational attainment were taken into account, the distinction between the sexes diminished substantially. Indeed several studies have shown socioeconomic status (SES) to be a stronger correlate of obesity among women than men (99-101). This also

highlights an alternative distinction-- education plays a more important modifying role for women than it does for men.

In addition to distinguishing between the sexes, we also contribute to the literature on immigrant health by examining trends in patterns of acculturation over time. BMI and WC increased among all nativity/length of U.S. residence categories for men. They increased slowest among the most recent immigrant group, implying that over the two decades of our analysis, anthropometric gradients may have become steeper; however, we cannot statistically reject the hypothesis that the gradient was of about equal size in the late 2000s as it had been in the early 1990s. Among women, we observed a statistically significant widening of the gradient, but only among the less educated. Education plays a more important modifying role for women than for men, not only in terms of the cross-sectional gradient in anthropometric outcomes but also in terms of changes in the nature of this gradient over time. Among immigrants, having more education may facilitate integration and acculturation into U.S. society, which may be accompanied by adoption of a more Westernized diet and sedentary lifestyle. Additional research will be necessary to explore the underlying reasons that education is observed to modify these relationships, and why its role as a modifier appears to be different for women than men.

In the context of Mexico's ongoing obesity epidemic, we anticipated some narrowing of the nativity/length of U.S. residence gradient over time. As BMI and WC in Mexico converge with the U.S., it is plausible that a similar convergence might be observed between Mexican migrants and the Americans they join. However, we observed

no such pattern. This may seem paradoxical, but we note that migrants are systematically selected from their country of origin; changes in the Mexican population average over time are not necessarily a reflection of the subpopulation that migrates to the U.S. The extent to which Mexican immigrants are positively selected on health is unclear, but one study that compared the weight of Mexican migrants to non-migrants demonstrated a lower prevalence of overweight among migrants (102). The patterns we observed over these 20 years may be driven by changes in the dynamics by which immigrants are selected from among their sending communities. Changes to U.S. immigration policy and to other economic and social factors that motivate immigration will likely continue to play an important role in shaping the health profile of immigrants in the future.

These results also speak to an important theme in the health disparities literature in the U.S. We have documented complicated interactions between gender, nativity, and educational attainment among the largest subgroup of Hispanics in the U.S. SES disparities in BMI and obesity have been extensively documented in the U.S., but much of the literature highlights that these disparities are particularly weak among Hispanics (23, 24, 103, 104). Our findings suggest that this overall average may mask important heterogeneity; SES gradients among U.S. born Hispanic women may actually be quite steep, but this pattern is obscured when findings are not disaggregated by sex and nativity. Moreover, our results imply that some of these gradients may not be stable over time; for example, the SES gradient among U.S. born Hispanic women appears to have gotten steeper between the late 1980s and late 2000s. These patterns may call for

interventions to thwart this trend, as well as a reexamination of patterns that were documented in the past.

Our study had several strengths. First, we used a large, nationally representative dataset that over-sampled Mexican-Americans over a large time span, permitting detailed examination of trends over time. Second, we used clinically-measured anthropometric indicators, which mitigates problems with validity and reliability inherent in self-reported measures. Third, unlike previous studies that explored anthropometric trends among Mexican-Americans, or that examined nativity differences at a single point in time, we were able to capture weight-related patterns both by nativity and time live in the U.S., and examined how these measures changed over time.

This work also had some important limitations. Although data on Mexican-Americans is intended to be nationally representative, it is unclear the extent to which undocumented individuals were captured. The undocumented are estimated to constitute more than half of the Mexican immigrant population in the U.S. and therefore represent an important segment of the population (105). Similarly, there is also a concern that data among newer immigrants more generally may not be adequately representative of all new Mexican immigrants to U.S. Other data sources may be necessary to better quantify health patterns for newer arrivals.

Reliance on cross-sectional data is also a limitation common to studies of immigrants and Mexican-Americans. We documented trends in anthropometry over time, but these estimates do not examine the same individual, and could very well represent individuals different on a number of unmeasured characteristics. Circular migration is not

uncommon, particularly among Mexican men (106), which complicates findings based on length of U.S. residence. Without the ability to follow the same individual over time, we cannot ascertain, for example, whether the higher weight among long-term immigrants is not merely a reflection of greater return migration of healthier individuals. Studies documenting migration patterns of Mexicans to the U.S. also reveal a greater likelihood of return migration in the wake of enactment of immigration policies aimed at legalization of long-term immigrants. After the passage of the Immigration and Control of 1986, for example, return migration rates increased dramatically (106), possibly biasing findings among long-term immigrants that remained in the U.S. after that point. If immigrants more physically capable of return travel are not represented in estimates of long-term immigrants, we may falsely attribute a decline in health among immigrants that remain in the U.S. to their greater exposure to U.S. society. In other words, rather than being viewed as a risk factor that contributes to weight gain, longer length of residence may instead be a reflection of who actually remains in the U.S. over the long-term.

Further research will be necessary to uncover the dynamics underlying the patterns we have reported. Nevertheless, these patterns have important implications for future chronic disease burden in the U.S. If the secular trends we report continue unabated, it has the potential to exacerbate socioeconomic health disparities among U.S.-born Mexican-American women. This development may be masked if researchers aggregate "Hispanics" as a single ethnic group when evaluating these trends. Migration processes are dynamic. As the social, political, and economic factors that influence it change, so will the nature of ethnic, socioeconomic, and gender disparities in health.

Table 4.1. Sample Characteristics by Nativity and NHANES Survey Period for Mexican-American Women and Men, Aged 20-64 Years

	NHANES III: 1988-1994				Continuous NHANES 1999-2004				Continuous NHANES 2005-2008			
N[†]	3175				3037				1937			
	Women		**Men**		**Women**		**Men**		**Women**		**Men**	
	1571		1604		1420		1617		923		1014	
	U.S. born	**Foreign born**	**U.S. born**	**Foreign born**	**U.S. born**	**Foreign born**	**U.S. born**	**Foreign born**	**U.S. born**	**Foreign born**	**U.S. born**	**Foreign born**
N[†]	908	663	821	783	693	727	707	910	443	480	385	629
Mean age, years	37.6	35.2*	37.2	32.5*	35.3	36	35.8	34.5	37.1	37.7	35.3	35
Education, %												
Less than high school	34.2	77.1*	33.6	76.3*	22.2	62.3*	25.2	63.4*	20.4	60*	20.2	67.4*
Completed high school	39.9	13.1	34.4	13.3	25.9	15.7	26.4	19.4	23.1	16.8	25.3	18.2
More than high school	25.9	9.8	32	10.4	51.9	22	48.4	17.2	56.6	23.2	54.5	14.3
Years in U.S. (among foreign born), %												
< 10 years	-	45.2	-	48.3	-	41.3	-	43.7	-	40	-	46.7
≥ 10 years	-	54.8	-	51.7	-	58.7	-	56.3	-	60	-	53.3
Mean body mass index (kg/m2)[€]	28.7	28.3	28.2	26.7*	29.5	29	28.8	27.7**	29.7	29.2	29.9[a]	27.9*[a]
Obese, %[€]	38.3	34.6	30.3	18*	42.8	35.6	35.5	25.3**	45.2[a]	41.4	36.3[a]	25**[a]
N[‡]	874	637	798	755	683	714	699	893	435	465	378	606
Mean waist circumference (cm)[€]	92.8	91.7	98	93.6*	94.7	93.3	99.4	96.3**	96.3[a]	94.5**[a]	102.3[a]	96.8*[a]
High risk waist circumference, % (men: ≥ 102 cm; women ≥ 88 cm)[€]	62.4	59.8	34.3	22*	64.9	62.7	42.5	28.4**	64[a]	67.3	40.1[a]	27**

*p ≤ 0.0001; **p < 0.05: comparing foreign-born to U.S.-born within survey period and by gender

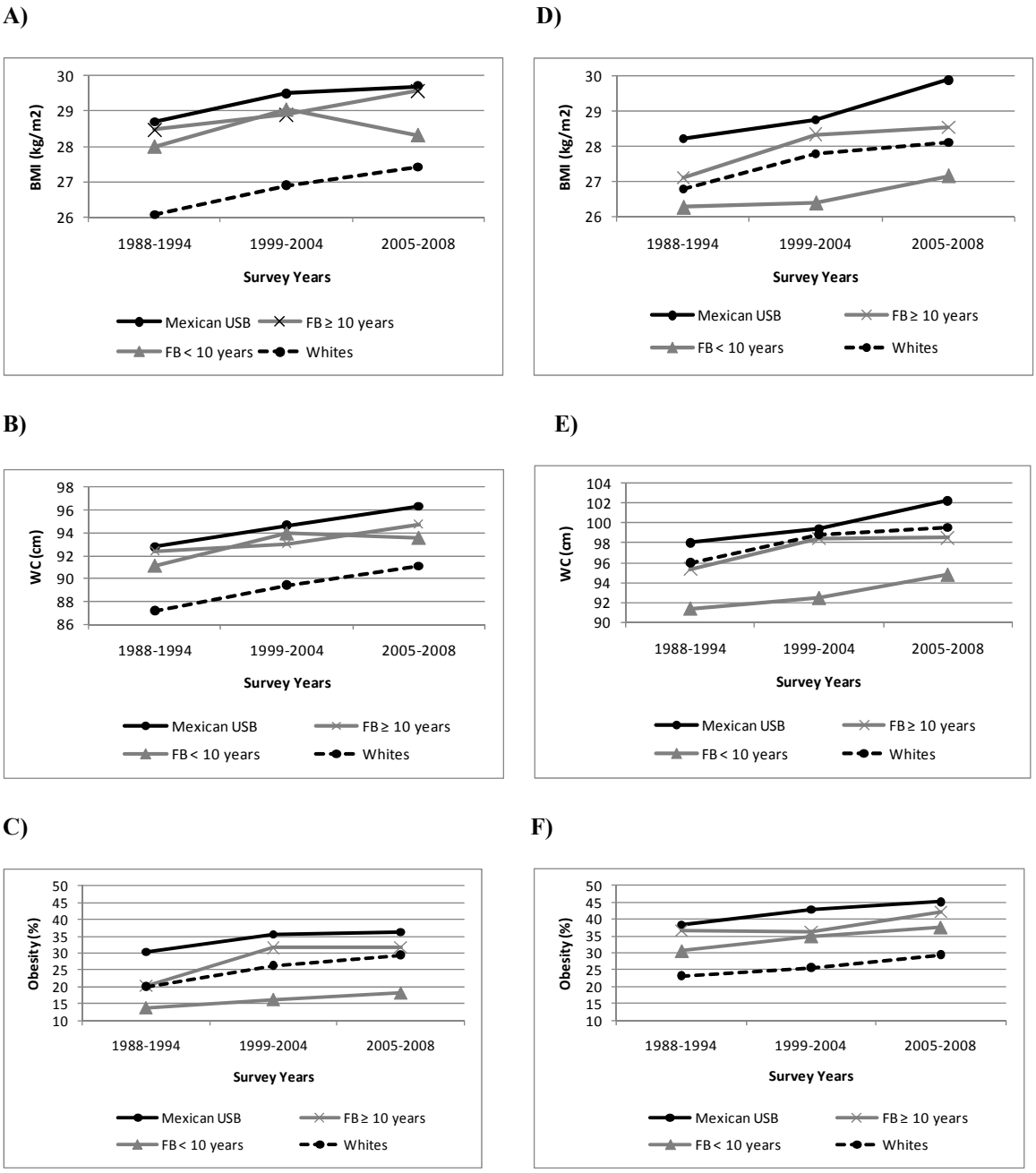
[a] p < 0.05; comparing respective nativity estimates in 2005-2008 to estimates in 1988-1994

[†]Number of individuals with complete information on body mass index, nativity, length of U.S. residence, and education

[‡]Number of individuals with complete information on waist circumference, nativity, length of U.S. residence, and education

[€]Estimates age-adjusted by the direct method to the year 2000 Census population using the age groups 20-34, 35-44, and 45-64

Figure 4.1. Age-adjusted body mass index (BMI), waist circumference (WC), and obesity prevalence for Mexican-American foreign-born (FB) by length of U.S. residence (< 10 years, ≥ 10 years) and U.S.-born (USB) men (A, B, C) and women (D, E, F) by National Health and Nutrition Examination Survey (NHANES) years



Estimates for whites presented for reference. Age-adjusted by the direct method to the year 2000 U.S. Census population using age groups 20-34, 35-44, and 45-64.

Table 4.2 - Adjusted Mean Differences in BMI and WC among Mexican-Americans by Nativity/Length of U.S. Residence and NHANES Survey Period

	MEN				WOMEN			
	BMI		WC		BMI		WC†	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Nativity/length of U.S. residence differences by period								
1988-1994								
U.S.born	ref	ref	ref	ref	ref	ref	ref	ref
Foreign born: ≥10 years	**-1.30 (0.31)***	**-1.33 (0.33)***	**-3.01 (0.79)***	**-3.39 (0.83)***	-0.57 (0.57)	-1.18 (0.61)	-0.88 (1.09)	-2.02 (1.16)
Foreign born: <10 years	**-1.97 (0.28)***	**-2.00 (0.29)***	**-6.18 (0.74)***	**-6.59 (0.76)***	-0.75 (0.39)	**-1.45 (0.44)***	-1.59 (0.83)	**-2.89 (0.90)***
1999-2004								
U.S.born	ref	ref	ref	ref	ref	ref	ref	ref
Foreign born: ≥10 years	-0.54 (0.64)	-0.61 (0.63)	-1.31 (1.60)	-1.84 (1.63)	-0.94 (0.59)	**-1.60 (0.54)***	-2.39 (1.52)	**-3.69 (1.33)***
Foreign born: <10 years	**-1.92 (0.63)***	**-2.08 (0.65)***	**-5.89 (1.77)***	**-6.63 (1.84)***	-0.90 (0.90)	-1.75 (0.91)	-1.94 (1.47)	**-3.62 (1.49)****
2005-2008								
U.S.born	ref	ref	ref	ref	ref	ref	ref	ref
Foreign born: ≥10 years	**-1.48 (0.49)***	**-1.65 (0.53)***	**-4.32 (1.29)***	**-5.13 (1.34)***	-0.20 (0.57)	**-1.03 (0.50)****	-1.84 (1.24)	**-3.49 (1.12)***
Foreign born: <10 years	**-3.19 (0.63)***	**-3.36 (0.64)***	**-8.92 (1.80)***	**-9.81 (1.80)***	-0.80 (0.46)	**-1.48 (0.51)***	-1.79 (1.09)	**-3.12 (1.30)****
Period trends by nativity/length of U.S. residence								
U.S. born								
1988-1994	ref	ref	ref	ref	ref	ref	ref	ref
1999-2004	0.55 (0.62)	0.64 (0.61)	1.87 (1.56)	2.18 (1.53)	0.92 (0.57)	**1.29 (0.57)***	2.45 (1.40)	**3.25 (1.34)****
2005-2008	**2.06 (0.59)***	**2.22 (0.59)***	**5.93 (1.59)***	**6.51 (1.60)***	0.78 (0.64)	1.20 (0.63)	**3.71 (1.24)***	**4.59 (1.24)***
Foreign born: ≥10 years								
1988-1994	ref	ref	ref	ref	ref	ref	ref	ref
1999-2004	**1.34**	**1.36**	**3.57**	**3.73**	0.55	0.87	0.94	1.57

	(0.34)*	**(0.34)***	**(0.88)***	**(0.89)***	(0.61)	(0.63)	(1.38)	(1.42)
	1.88	**1.90**	**4.62**	**4.76**	1.15	**1.35**	**2.74**	**3.12**
2005-2008	**(0.48)***	**(0.48)***	**(1.35)***	**(1.38)***	(0.63)	**(0.63)***	**(1.37)****	**(1.39)****
Foreign born: <10 years								
1988-1994	ref	ref	ref	ref	ref	ref	ref	ref
			2.17		0.77	0.99	2.11	2.52
1999-2004	0.59 (0.52)	0.56 (0.52)	(1.45)	2.14 (1.42)	(1.06)	(1.03)	(1.70)	(1.67)
			3.19		0.73	1.17	**3.52**	**4.36**
2005-2008	0.84 (0.51)	0.86 (0.53)	(1.62)	3.28 (1.67)	(0.82)	(0.79)	**(1.67)****	**(1.63)***
Education								
Less than high school		ref		ref		ref		ref
						-0.98		-1.66
Completed high school		0.31 (0.35)		0.30 (0.89)		(0.50)		(1.00)
				-2.06		**-2.15**		**-4.25**
More than high school		-0.46 (0.38)		**(0.96)****		**(0.58)***		**(1.23)***
p-interaction (nativity/length of residence* period)	0.2671	0.2338	0.539	0.4164	0.9372	0.9615	0.9084	0.8205

*p< 0.01; **p<0.05

BMI, body mass index; WC, waist circumference

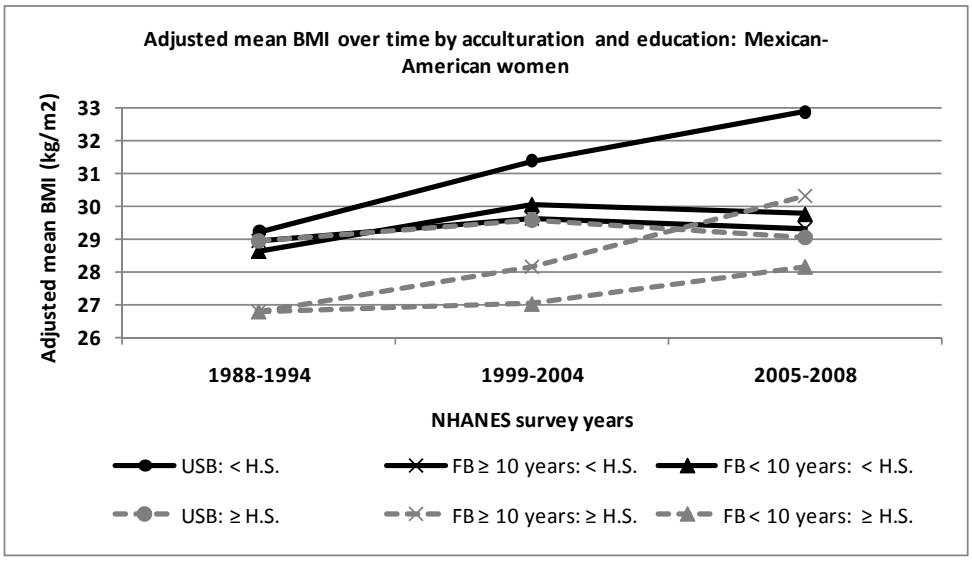
Model 1 adds age, age^2, nativity/length of U.S. residence, NHANES period, and interactions between age and period, and nativity/length of U.S. residence and period

Model 2 further adjusts for education

†WC models for women did not require age^2 term

In all models, referent group recoded to obtain relevant estimates within and across time periods.

Figure 4.2. Adjusted mean body mass index (BMI) by nativity/length of U.S. residence among Mexican-American women by level of educational attainment across National Health and Nutrition Examination Survey (NHANES) years



Abbreviations: USB = U.S.-born; FB = foreign-born; H.S. = high school. Model adjusted for nativity/length of U.S. residence, age, age^2, survey period, education, nativity/length of U.S. residence*survey period, age*period, nativity/length of U.S. residence*education, education*period, and nativity/length of U.S. residence*education*period. Estimates shown were calculated to correspond to the mean age of the female sample (age=36).

Chapter 5

Conclusion

Summary of Findings

This dissertation expands upon the literature as it relates to immigrant health in two key ways: by applying a longitudinal perspective and by examining heterogeneity in the relationship between nativity/length of U.S. residence and BMI and WC. Understanding the factors that shape immigrant health trajectories may guide the design of interventions for this rapidly expanding segment of the population. The three papers in this dissertation specifically examined: 1) differences in the rates of WC increase among U.S. and foreign-born Hispanic and Chinese adults; 2) the role of the neighborhood environment in moderating the relationship between nativity/length of U.S. residence and WC among Hispanics and Chinese adults; and 3) variation over time in the relationship between nativity/length of U.S. residence and body mass index (BMI) and WC among Mexican-American adults. The primary conclusion was that longer exposure to the U.S. context does not have the same health implications for all immigrants.

Chapter 2 used prospective data from the Multi-Ethnic Study of Atherosclerosis (MESA) to investigate whether Hispanic and Chinese foreign-born participants had more rapid rates of WC increase relative to their U.S.-born counterparts. Both Hispanics and Chinese foreign-born individuals had a lower mean WC at baseline, and there was no

evidence that rates of WC increase exceeded rates among the U.S.-born. This finding is inconsistent with the common interpretation of most cross-sectional studies which imply a greater rate of weight increase among immigrants, such that averages eventually approach those of the U.S.-born. Cross-sectional analyses may conflate cohort or age effects with the effects of time in the U.S. A longitudinal examination is essential to adequately capture the association between individual-level change and longer time in the U.S. However, when Hispanics were disaggregated by Mexican-origin status, Mexican immigrants had a greater rate of WC increase relative to both U.S.-born Mexican-Americans, and non-Mexican Hispanic immigrants. This pattern was even stronger among Mexican immigrant women. There are several plausible explanations for this finding. First, there a larger proportion of non-Mexican Hispanics were long-term immigrants than Mexican Hispanics. Since a more rapid rate of WC increase was found among more recent Mexican immigrants, steeper increases among foreign-born Mexican Hispanics overall may merely reflect differences in the distribution of years lived in the U.S. between the two Hispanic ethnic groups. However, among non-Mexican Hispanics, WC trajectories did not differ by baseline length of U.S. residence as was the case among Mexican Hispanics. Second, behaviors, beliefs, and practices acquired in the country of origin are also likely to dictate health patterning after migration. Legal status, factors that motivate migration, and even skin color vary by ethnicity and can contribute to variation in health patterning. Moreover, certain ethnic groups may be more likely to migrate to distinct regions in the U.S. (e.g. Cubans to Miami, Puerto Ricans and Dominicans to the NYC area, Mexicans to California, Texas, and the South, etc). These regions differ in the

quality of their built environments, and the political and social climate with respect to receptivity of immigrant groups. Bivariate analyses in MESA suggested that Mexican Hispanics were more concentrated in Los Angeles, CA and St. Paul, MN, while non-Mexican Hispanics were overwhelmingly concentrated in New York, NY. Mexican Hispanics also lived in environments with poorer availability of healthy food and poorer walkability. A more comprehensive examination of the inter-relationship among Mexican-origin status, the neighborhood environment, and WC change was not feasible due to sample size. However, the confluence of cultural and behavioral factors associated with country of origin, as well as characteristics of the receiving environment may have contributed to the heterogeneity observed by ethnicity among Hispanics.

Chapter 3 also used prospective data from MESA to examine the role of the neighborhood residential environment in moderating the relationships between nativity/length of U.S. residence and baseline WC and WC change among Hispanics and Chinese participants. The association between longer time in the U.S. and a decline in health is typically thought to arise from environmental factors that discourage the practice of healthy behaviors. There was a larger cross-sectional difference in mean WC between foreign-born and U.S.-born Hispanics in neighborhoods characterized by greater healthy food availability. This finding reflected the fact that WC was lower among the foreign-born in these better neighborhoods. This pattern may suggest a greater health vulnerability among Hispanic immigrants to the dietary resources available in their neighborhoods. However longitudinal nativity differences were not modified by any of the neighborhood indicators. Among Chinese participants, the walkability of the

environment modified the longitudinal relationship between length of U.S. residence and WC change. Specifically, the impact of more years in the U.S. on WC increase was weaker in more walkable neighborhoods. Taken together, better food environments enhanced the protective cross-sectional association between foreign-birth and lower WC in Hispanics, and better walking environments buffered the adverse effect of longer length of U.S. residence on WC increase in Chinese. Assuming a causal relationship between neighborhood factors and WC and WC change, these findings point to the contribution of contextual factors in shaping WC patterning for Hispanic and Chinese immigrants.

Mexico is the largest immigrant sending country to the U.S. (57) In light of Mexico's emerging obesity epidemic, the protective effect of foreign-birth and shorter length of U.S. residence on BMI and WC may be expected to vary over time. Chapter 4 used repeated cross-sections from NHANES to examine secular variation in the relationship between nativity/length of U.S. residence and BMI and WC among a nationally representative sample of Mexican-Americans. There was a graded relationship between longer length of U.S. residence and higher BMI and WC (with the U.S.-born having the highest estimates). This relationship did not change substantially between 1988-1994 and 2005-2008. However, there were important variations in this patterning by gender and by socioeconomic status. Among women, BMI and WC differences by nativity were only evident after adjusting for educational attainment. Moreover, trends in this gradient varied by education; notably, U.S.-born women with less than high school education had increasingly higher mean BMI and WC over time, magnifying the gradient

by nativity. Among women with high school or more education, BMI and WC increased for the foreign-born, narrowing the gradient. The pattern among the low-educated U.S.-born Mexican-American women was especially troubling. A majority of Mexican foreign-born women were characterized by low education. Studies show that SES is often transmitted across generations (107, 108). If the U.S.-born daughters of low-educated Mexican migrants continue on the same trajectory, this will exacerbate already existing health disparities.

In chapter 2 of the dissertation, there were smaller nativity differences in baseline WC among women of Mexican-origin than among men in MESA, consistent with findings from NHANES. However, from a longitudinal perspective, WC increased faster among both male and female Mexican immigrants than among the U.S.-born, in contrast to the findings observed using NHANES data (chapter 4). Differences between the MESA and NHANES samples limit comparability of results between these two studies. MESA is an older sample with no clinical CVD disease at baseline. NHANES includes a greater age range (20-64 years for this analysis) and is more likely to be representative of Mexican-Americans in the U.S. than MESA. More recent immigrants in MESA are also apt to be quite different from recent immigrants in NHANES. Individuals that migrate in older age tend to do so for family and/or medical reasons, whereas younger individuals tend to move for labor opportunities and thus may be more health-selected (106, 109). These findings highlight the heterogeneity that may be present even when examining health patterns within the same ethnic group.

Limitations

Although longitudinal data were used for the first two aims of this dissertation, the third aim used cross-sectional data from NHANES. Migration and subsequent exposure to a new environment produces changes that occur within an individual. Longitudinal data are necessary to examine this process. Using NHANES, trends in anthropometry were documented over time, but these estimates do not examine the same individual, and may represent individuals different on a number of unmeasured characteristics. However, often times there is a tradeoff between using data that is nationally representative, and using data that employs a prospective, and perhaps more valid approach when examining processes that occur within an individual over time. Although use of cross-sectional data remains a limitation here, one strength of this dissertation is the use of both longitudinal data that is likely to be less representative of a population and paired with the use of cross-sectional data that is intended to be nationally representative.

Another limitation relates to the way the process of acculturation was operationalized. Simple proxy measures, such as nativity and years lived in the U.S., were used to characterize this complex and multi-dimensional process (9, 11). Exposure to differential cultural and socio-political features of the host country environment, variation in opportunity for socioeconomic advancement, and the influence of characteristics associated with a migrant's country of origin all converge to shape the acculturation process (10, 11). However, currently there is no standardized way to measure this construct. Moreover, the goal of this dissertation was not to measure the changes in values, beliefs, and attitudes that are associated with greater acculturation to

the host society. Rather, these simple descriptors were used to facilitate examination of the heterogeneity in immigrant populations. These findings can then be used as a basis from which investigators can begin to uncover what factors shape trajectories of immigrant health.

In chapters 2 and 3, a median follow-up of 5 years was a relatively time short timeframe for assessing change in WC. For many individuals, change in WC may have already occurred prior to baseline, and was also likely affected by other factors accumulating over the life course. As a result, this may have precluded detection of any significant change in WC for some groups. Nevertheless, no other studies, as of this writing, have examined health patterning among immigrant adults from a longitudinal perspective. Future follow-up of MESA participants will permit examination over a longer period of time.

A number of analyses were also likely constrained by sample size limitations. Small cell sizes for the U.S.-born, particularly non-Mexican Hispanics and Chinese in chapter 2, may have limited statistical power to detect associations between nativity and WC change for these groups. Non-Mexican Hispanics represent a very heterogeneous group whose classification as a single homogenous group could have also masked important patterns. In chapter 3, the small number of U.S.-born Chinese-Americans did not permit examination of heterogeneity by neighborhood environment in the association between nativity and WC. Similarly, small numbers of newer Mexican immigrants in NHANES may have limited power to detect variation in anthropometric trends between

these and other groups. Sub-analyses by gender are also important in research of immigrants, but were only possible in some chapters.

U.S.-born individuals were aggregated as a single group irrespective of immigrant generational status. Second generation individuals (i.e. children of immigrants) may be distinct from individuals that are third generation or higher due to differences in their social experiences having been raised in a family of immigrants (79). Factors associated with their upbringing may contribute to differences in behaviors and health outcomes relative to individuals that are third generation or higher. However small sample sizes among some of the U.S.-born ethnic groups precluded examination of health patterning by generational status.

MESA is an older, yet healthy cohort sampled from selected sites; it is not clear how well findings would generalize to other immigrant groups in the U.S. Although NHANES is intended to be nationally-representative, there is some concern that undocumented immigrants, which are estimated to constitute more than half of the Mexican immigrant population in the U.S. (105), are not well represented. Likewise, it is unclear how well newer Mexican immigrants are represented more generally, which may have implications for the representativeness of the findings among this subgroup.

Public Health, Policy, and Research Implications

This dissertation offers insight into heterogeneity of BMI and WC patterning among immigrants to the U.S. Longer time in the U.S. was associated with a decline in health for some, but not all of the groups that were studied. However several questions remain. For instance, what is the mechanism through which Mexican-origin status among

the foreign-born is associated a more rapid increase in WC? Alternatively, why were foreign-born non-Mexican Hispanics protected against increases in WC? Baseline diet and measures of leisure-time physical activity were tested as mediators but did not fully explain these relationships. Other forms of activity, such as occupational or transportation-related activity, may be better measures of energy expenditure, particularly in a population in which leisure-time physical activity is known to be low.

There may also be other mechanisms through which longer time in the U.S. can impact weight gain, especially central adiposity. Immigration is accompanied by stressful socio-cultural and environmental changes. Higher physiological stress, measured using cortisol biomarkers, has been positively associated with central adiposity (110-112). As a result, higher stress may also be a pathway through which longer time in the U.S. contributes to increasing waist circumference. Other psychosocial measures, social support networks, discrimination, and legal status are other factors to be considered in future research.

A more thorough unpacking of what is meant by longer 'length of U.S. residence' is also warranted. Although it is intended to proxy a process of cultural and behavioral change, the concept of 'culture' remains notoriously difficult to measure and even define (113). In this sense, qualitative studies may be better to inform conceptualization of some of these more abstract concepts and processes.

The health deterioration thought to result from longer time in the U.S. has been attributed to environmental factors. However the social and cultural environment where immigrants reside can also influence the process of acculturation itself. Immigrants living

in disadvantaged neighborhoods, for example, may have limited access to resources to education and employment which in turn could create obstacles for upward mobility and possibly better health. Similarly, foreign-born individuals living in neighborhoods marked by poverty may merely be 'acculturating' to the negative health behaviors that have been shown to be prevalent in these neighborhoods. While living in immigrant enclaves may hinder the acculturation process by slowing the adoption of English language skills, enclaves may also confer benefits through social networks and the preservation of cultural norms that may be more protective for health (41). Future work will need to account for the contextual influences that simultaneously shape both the acculturation process itself as well as trajectories for health.

Although this dissertation begins to uncover the neighborhood-level determinants of immigrant health, the neighborhood scales used were based on a subjective characterization of the residential environment. It remains unclear how other structural features of the environment such as fast food store density, availability of parks and recreational facilities, etc. may be relevant for immigrants. Subjective measures of the built environment may not adequately reflect the true quality and availability of resources. Although many studies have shown both perception- and GIS-based measures of the environment to be associated with obesity, as well as diet and physical activity (34, 35, 91), perception is likely to be linked to individual psychological, cultural, and behavioral factors (114). Other characteristics such as low income, poor health, and less time in the neighborhood have also been associated with greater mismatch between perception of the built environment and availability and quality of structural resources

(115). In these dissertation analyses, the neighborhood measures used may adequately characterize the true nature of the built environment. However it is also possible that limited awareness or access to resources could have resulted in poorer ratings with respect to availability of healthy food, for example, that may not necessarily match with the reality in the neighborhood. Relying solely on perception-based measures may misestimate the true association between the neighborhood and anthropometric outcomes. However, subjective measures may also capture relevant neighborhood dimensions not well-characterized by GIS-based measures. Supermarket density is often used as a marker of healthy food availability, for example, but respondent information may better indicate whether the food sold is truly healthier in nature. Perception is also more likely to shape utilization of available resources. Future work that incorporates multiple measures of neighborhood quality will be important to understand what environmental features may be most relevant to health for immigrants to better guide interventions. Chapter 4 introduced discussion of how national immigration policies (such as the Immigration Reform and Control Act of 1986) may have implications for the health selection of new immigrant arrivals, and how these policies may contribute to health patterning of immigrants that reside in the U.S. Implementation of stricter border controls, for example, may increasingly select healthier immigrants who are more physically capable of migrating to the U.S. in light of greater obstacles to entry. On the other hand, such policies may also select for immigrants living under more desperate circumstances, which may also influence health patterning. Once in the U.S., national and state immigration policies, such as those adopted by the Arizona state senate in April 2010, may further

marginalize already vulnerable populations living in the U.S. Increased marginalization may precipitate a more rapid decline in health among immigrants. Future legislation of immigration is anticipated, especially with regards to Mexican migration. It will be critical for future work to adapt a multi-level framework that accounts for the influence of these more macro-level policies when examining health patterns among immigrants.

These dissertation papers provide evidence of variability in immigrant health trajectories which can assist policy makers in designing more targeted interventions. Efforts aimed at reducing obesity and promoting healthy behaviors among immigrants, or non-white populations more generally, are limited. A review that evaluated population-based interventions to promote healthy eating and active living in communities of color demonstrated a paucity of interventions; among the few strategies that have been tested, their effects on health have been modest to none (116). As a result, an increasing number of studies have focused efforts on qualitatively evaluating the needs and cultural perspectives of specific communities (117-119). There is increasing recognition that both community and individual-level interventions that may be successful in predominantly white populations may not translate to other groups. One study that explored barriers to physical activity among a diverse sample of Latinas, African-Americans, Native Hawaiian, and Hmong immigrants emphasized the importance of activities that encourage the involvement of family and friends over more individually-oriented activities. Although all groups were aware of the connection between physical activity and health, immigrant groups especially, construed physical activity as a natural part of their daily routine that did not require additional planning or active incorporation (120).

This perspective may explain why levels of leisure-time physical activity among immigrants are often lower than among U.S.-born individuals (7, 121). In many non-Western countries, recommended levels of energy expenditure are achieved through the daily activities associated with one's occupation and lifestyle, rather than through leisure-time physical activity. For this reason, many immigrants may not perceive the value of incorporating additional exercise into their daily routine, especially in the context of severe time constraints. From this perspective, interventions at the community-level that facilitate more utilitarian activity may be more relevant for some immigrant groups.

Participants from this same qualitative study also preferred to engage in activities that were inexpensive, accessible in their communities, and that were primarily performed outdoors rather than inside a facility (120). Another qualitative study of Latina immigrants cited lack of time, lack of child care, and issues surrounding 'machismo' and gendered social norms that created barriers against physical activity (119). Health behavior interventions that encourage involvement of the family, or of mothers and children together, may be more effective at addressing the specific needs of immigrant populations.

Efforts to preserve the health of immigrants and stall the deterioration of health that accompanies exposure to a new and perhaps more obesogenic environment must be based on a more nuanced understanding of the migration experience. The immigration and acculturation processes have not always been linked to negative consequences as they have also been associated with expanding opportunities for immigrants with respect to education, income, and upward mobility. Preserving these positive aspects of

acculturation while facilitating retention of protective factors for health may be part of the strategy to maintaining good health in this rapidly expanding segment of the population.

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