The Metabolic Health and Mortality Patterns of the US Hispanic Population: Exploring Causes and Consequences

by

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Dedication

To my Nana Rose (*1921-2021*),

this is for you.

Had you been born at a different time, in a different society, this degree would have been yours first. I only wish you could have seen me complete it. Thank you for showing me that learning happens every day, everywhere, forever—an endless, curious pursuit that we pass from one generation to the next.

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Abstract

Hispanics in the United States (US) generally live longer and experience better health than non-Hispanic whites despite their lower socioeconomic status; a phenomenon commonly termed the Hispanic paradox. Yet over the past few decades, rising obesity levels in the US and Mexico have all disproportionately affected the US Hispanic population, and it remains unclear if and how these trends could reshape future health and mortality patterns. Centering different demographic processes and key segments of a growing US Hispanic population, each paper of the dissertation approaches the question of how obesity and related metabolic conditions may impact the Hispanic paradox through a distinct lens informed by methods and perspectives from social demography, population health, and medical sociology.

Using a nationally representative sample of adults from the National Health and Nutrition Examination Study (NHANES), Paper 1 assesses and seeks to explain differences in metabolic syndrome (MetS) risk by race-ethnicity, country of origin, and duration of residence in the US to evaluate whether recent Mexican immigrants continue to exhibit a health advantage in this area. Recent Mexican immigrants were found to hold a metabolic health advantage over US-born whites due to their younger age structure. However, a decomposition analysis further reveals that recent Mexican immigrants would retain a MetS advantage, even after adjusting for age differences, if they were to achieve parity with US-born whites on education, income, and food security. This highlights these as key areas of social policy intervention to protect and preserve the health of newly-arriving Mexican immigrants with increasing time spent in the US.

Looking to the future, Paper 2 again leverages data from NHANES and brings in supplemental sources to project the impact of observed, historical patterns in obesity prevalence among non-Hispanic whites and US-born and foreign-born Hispanics on age-40 life expectancy (e_{40}) over three decades, from 2015 to 2045. Somewhat counter to expectations set by historical trends and the few existing studies on this topic, I find that obesity is expected to have a large and comparable effect on mortality for all groups, and thus is unlikely to significantly reshape the existing Hispanic advantage in life expectancy within the foreseeable future.

Finally, expanding the focus of the dissertation in terms of life course and geography, Paper 3 combines cross-national data from the US Health and Retirement Study (HRS) and Mexican Health and Aging Study (MHAS) to explore disparities in metabolic health conditions and attributable mortality risks across first- and later-generation Mexican-origin populations in the US and Mexico as compared to US-born whites. Despite considerable focus on obesity as an emergent threat to Hispanic health and longevity, my findings reveal significant disparities primarily in the distribution of physiological metabolic conditions—particularly, elevated blood glucose levels (i.e., prediabetes/diabetes)—and attributable mortality risks burdening older Mexican-origin populations on both sides of the border relative to US-born whites. Future research should focus on managing diabetes as a key area of preventable mortality that is currently driving disparities between aging foreign-born and US-born Mexican populations relative to US-born whites.

Taken together, these studies update current understandings about the Hispanic paradox and highlight emergent areas of vulnerability to guide future interventions as part of a comprehensive strategy to protect and promote the health and longevity of Hispanics living in the US, while also seeking to reduce health inequities across the entire US population.

Chapter 1 – Introduction

Hispanics in the United States (US) have held a life expectancy advantage over non-Hispanic whites for nearly three decades, an advantage that has been most pronounced among foreign-born Hispanics, and particularly those of Mexican origin (Cho et al., 2004; Hummer et al., 2000; Lariscy et al., 2016; Markides & Coreil, 1986). This gap in life expectancy has not only been persistent, but also quite pronounced, with US-born Hispanic adults over the past decade expected to live roughly two years longer than non-Hispanic white adults, and foreign-born Hispanics holding a longevity advantage extending to three-to-four years (Frisco et al., 2019). Further, Hispanics in the US also have lower levels of morbidity and hold some health advantages relative to non-Hispanic whites and the US population overall (Argeseanu Cunningham et al., 2008). Hispanic health advantages are strongest among recent immigrants, particularly those from Mexico (Cho et al., 2004). As such, the favorable health profile of foreign-born Hispanics is commonly referenced as a prominent example of the "immigrant health advantage"—a pattern largely attributed to selective migration, with in-migrants selected positively and out-migrants selected negatively on health and related attributes, as well as to differences in key health behaviors favoring first- and later-generation Hispanic immigrants, particularly smoking (Blue & Fenelon, 2011; Fenelon, 2013; Markides & Eschbach, 2005).

However, Hispanics' longstanding and well-documented advantages in longevity and health are difficult to reconcile against their socioeconomic disadvantages, in terms of income and educational attainment, relative to the rest of the US population (Gonzalez-Barrera & Lopez, 2013). One of the strongest and clearest associations documented in the sociomedical literature has long been the positive socioeconomic-health gradient that persists across all levels of socioeconomic status (Adler et al., 1994; Adler & Ostrove, 1999) and which endures as a fundamental cause of health for all racial-ethnic groups in the US aside from Hispanics (Link & Phelan, 1995). Given this, Hispanics' contradictory health and mortality advantages over non-Hispanic whites have collectively come to be known as the *Hispanic paradox* (Markides & Coreil, 1986), representing a major fixture of the demographic and population health literatures that has garnered considerable research attention over the past few decades.

Despite the durability of these puzzling yet prominent health and mortality patterns by race, ethnicity, and nativity in the US there is reason to question whether the Hispanic paradox, in both health and mortality, will persist in the future. The rise of obesity and related metabolic health conditions in recent decades has disproportionately impacted both Hispanics born in the US (McTigue et al., 2002; Van Hook et al., 2020), as well as native-born Mexicans (Barquera & Rivera, 2020; Popkin et al., 2012), who represent the largest origin population of Hispanic immigrants to the US (Flores, 2017). Further, over the same time period, the prevalence of smoking has decreased across the entire US population, likely weakening the future influence of this once key contributor to upholding the Hispanic health and mortality advantage (Bostean et al., 2017). These shifts in population health and health behaviors have led some senior researchers to question whether the rise in obesity, and heightened susceptibility to major metabolic health risks such as diabetes and cardiovascular disease, could erode Hispanics' longstanding longevity advantage in the US within the foreseeable future (Goldman, 2016; Hummer & Hayward, 2015).

If anything, the pertinence of this question has only been heightened in recent years, particularly with the onset of the novel coronavirus disease—or, COVID-19—pandemic. Within the 2020 calendar period, driven by disproportionate rates of infection and mortality from the SARS-CoV-2 virus, Hispanics' life expectancy advantage over non-Hispanic whites was reduced by more than half (Arias & Kochanek, 2021). While the contributing factors to the elevated rates of infection and severe outcomes from COVID-19 faced by Hispanics and other minoritized racial-ethnic groups in the US relative to non-Hispanic whites are complex and multifactorial, it has also become clear that higher weight and associated chronic metabolic health conditions were a significant contributor to their rapid and disproportionate rise in COVID-related mortality outcomes throughout the pandemic (Andrasfay & Goldman, 2021; El Chaar et al., 2020; Martínez-Colón et al., 2022; Popkin et al., 2020). While this significant period reduction in life expectancy is not expected to carryover with the same magnitude in future years, the 2020 calendar period and COVID-19 pandemic effectively served as a concentrated and accelerated case study to illustrate how shifts in the distribution of obesity across racial-ethnic groups in the US may leave weight-burdened groups increasingly vulnerable to heightened mortality risks; whether those mechanisms are direct—through an accumulation of metabolic health complications—or, indirect—through heightened susceptibility to infection and severe outcomes from outside assaults, such as a novel viral infection like COVID-19.

However, despite the question of how obesity will impact the future health and mortality of Hispanics in the US being prominently raised by leading researchers, and further evidence of the potential consequences accumulating in recent years, little research to date has directly sought to empirically address the current and future vulnerabilities, the causes and consequences, to the health and longevity of the US Hispanic population that may be introduced by the trends in obesity observed over the past few decades. As such, in this dissertation, I draw upon methods and perspectives from social demography, population health, and medical sociology to broadly explore the current and future influence of obesity and related metabolic conditions in shaping health and mortality patterns between US-born and foreign-born Hispanics relative to US-born non-Hispanic whites to better inform tailored policy responses and strategic interventions to preserve and protect the health and longevity of Hispanics living in the US. In particular, I pursue three general lines of inquiry about how obesity has, and could continue to, impact the health and mortality of Hispanics in the US with a particular emphasis on key dimensions of the Hispanic paradox that have been extensively documented in the demographic and population health literatures, and thus, represent critical gaps in current knowledge and expectations for the future. Moreover, these gaps all align with key demographic processes—namely, immigration, population change, and aging—underscoring the unifying thread that my training in demography has played in shaping my thought and praxis as an interdisciplinary researcher straddling the fields of population health and sociology.

To address the first gap, I ask, in light of epidemiological trends in weight gain and obesity on both sides of the US southern border, do recent Mexican immigrants to the US still hold a significant immigrant health advantage in metabolic syndrome over US-born groups? Second, will the trends that have been observed in rising obesity levels cause an erosion of the Hispanic life expectancy advantage in coming decades? And, third, given evidence that the Hispanic life expectancy advantage has already been lost for US-born Hispanics over the age of 65 (Lariscy et al., 2015), and the rapid growth of older Hispanics as a US demographic group (Vincent, 2010), what insight into the current and future vulnerabilities can be gained by understanding the current distribution of metabolic conditions and mortality risks across older Mexican origin populations on both sides of the border? Each chapter in the body of the dissertation will take up one of these three lines of inquiry and pursue specific aims to fill in critical knowledge gaps that are necessary to address as part of a comprehensive strategy to inform current understandings and possible future actions that may be taken to protect and promote the overall health and longevity of Hispanics living in the US and reduce health inequities across the US population as a whole.

Paper 1 focuses on the Hispanic health advantage in metabolic syndrome among recent and later immigrants, Paper 2 projects future obesity levels among non-Hispanic whites and US- and foreign-born Hispanics to assess future impacts to mid-life life expectancy and the potential reshaping of mortality patterns, and Paper 3 uses cross-national data of older adult populations to explore the current distribution of metabolic conditions and associated mortality risks across Mexican-origin populations in the US and Mexico as compared to US-born whites and US-born Mexican Americans. To further introduce the dissertation project, I detail the approach, rationale, and specific aims of each study below, before presenting them in their entirety in the chapters that follow. Finally, following the presentation of the three studies, I conclude the dissertation with a review of key findings and contributions, as well as a broader discussion of the implications of this work for population health and policy.

Paper 1 – Mexican Immigrant Health Advantage in Metabolic Syndrome? Decomposing the Effects of Demographic, Socioeconomic, and Health Behavior Characteristics

In Paper 1, I explore how dramatic shifts in obesity on both sides of the US-Mexico border over the past few decades have impacted the metabolic health of Mexican immigrants to the US relative to US-born groups. In so doing, I also seek to highlight potential social policy interventions to promote health equity for current and future immigrants. For this study, I use nationally representative data from the National Health and Nutrition Examination Study

(NHANES), which uniquely combines examination-based biomarker data on all dimensions of metabolic syndrome (MetS) alongside a full suite of sociodemographic variables that can be leveraged to explain current patterns in metabolic health among Mexican immigrants to the US based on duration of residence, as well as in comparison to US-born groups. This combination of biological and sociodemographic data is uniquely positioned to inform interventions to better promote health equity on the basis of race-ethnicity/nativity in the US, in both the near and long-term. Specifically, the study is organized to address the following aims to fill knowledge gaps around how binational metabolic health trends have impacted the Hispanic paradox and immigrant health advantage:

1. To compare the metabolic profiles of adult-aged US-born whites, US-born Mexican Americans, and recent and earlier Mexican immigrants to evaluate whether recent Mexican immigrants hold a metabolic health advantage.
2. To assess the contribution of demographic, socioeconomic, and health behavior characteristics to observed population health gaps by race-ethnicity, country of origin, and duration of residence in the US.

Paper 2 – Erosion of the Hispanic Paradox? Projecting the Effects of Obesity on Future Life Expectancy in the US

While Paper 1 focuses on current patterns of metabolic health and how they may have been impacted by cross-national epidemiological shifts in obesity, Paper 2 looks to the future to characterize forthcoming consequences of obesity trends and to assess their potential to reshape long-standing US mortality patterns. Specifically, I estimate a series of obesity projections from 2015 to 2045 for US-born whites, US-born Hispanics, and foreign-born Hispanics and relate these projected shifts in obesity to impacts on life expectancy at mid-life. To accomplish this, I draw upon data from nationally representative population health surveys—including NHANES and the National Health Interview Survey (NHIS), as well as demographic data from the American Community Survey (ACS), US Census Population Projections, and US life tables published by the National Center of Health Statistics (NCHS)—to estimate specific mortality risks by BMI category for each racial-ethnic/nativity group and to ensure that my demographic projections incorporate expected shifts in the overall size and demographic composition of the US population over the next three decades. This study, innovative in its scope and structure, promises to inform future expectations about how recent trends in obesity stand to impact US mortality patterns in the future, and thus lays out clear implications for the potential of preventive efforts to mitigate obesity and reduce its impact as a preventable source of mortality for the entire US population, as well as for specific racial-ethnic/nativity groups. The study pursues two specific aims related to the current knowledge gap around if and how recent trends in obesity, currently disproportionately affecting US-born Hispanics, will continue in the future and what this may portend for the continuance of the Hispanic paradox in mortality. The specific aims include:

1. Project what obesity distributions will look like for male and female US-born Hispanics, foreign-born Hispanics, and US-born whites over the next three decades starting with a nationally representative sample of adults living in the US in 2015.
2. To estimate the impact of shifting obesity distributions on future life expectancy three decades into the future to evaluate whether the Hispanic paradox in mortality is expected to persist or erode.

Paper 3 – Metabolic Health and Mortality Among Older Hispanics in the US and Mexico: Focusing on the Role of Diabetes

Papers 1 and 2 largely focus on current patterns and future implications for US metabolic health patterns and mortality consequences in middle adulthood, while Paper 3 shifts focus to later life in effort to understand unique vulnerabilities that face a rapidly aging and diversifying US population. In making this transition, I introduce two additional data sources to round-out the dissertation—the US Health and Retirement Study (HRS) and the Mexican Health and Aging Study—which are harmonized population surveys of older adult health in the US and Mexico, respectively. Combining these two surveys into a single binational dataset affords the opportunity to gain a more detailed view of the current patterning of metabolic health and associated mortality risks among aging first- and later-generation Mexican immigrants to the US, relative to both non-migrants in their country of origin and the US population overall. A careful analysis of this unique data source could go a long way in informing strategies to reduce potential mortality risks and anticipate long-term care needs for a rapidly aging and diversifying US population over the coming decades. This study tackles three specific aims around perhaps the most underfilled knowledge gap addressed in the entire dissertation project—that is, the binational patterning of metabolic health and mortality risks among older Hispanics, currently the only age segment documented to have already lost their relative mortality advantage in recent years (Lariscy et al., 2015). The specific aims include:

1. Among adults over the age of 50, to determine the current distribution of metabolic health conditions across Mexican origin populations—both those living in Mexico and those who have migrated to the US—as compared to US-born whites and US-born Mexican Americans.

2. To explore whether differences in the distribution of metabolic health conditions translate into differences in the associated population attributable mortality risks.
3. To assess how controlling metabolic conditions with the highest mortality risk would compare to the effect of eliminating a known high-risk behavioral exposure, such as smoking.

Taken together, these three studies—and the dissertation project as a whole—seek to use the question that renowned population health scientists Robert Hummer, Mark Hayward, and Noreen Goldman first posed nearly a decade ago of whether recent trends in obesity might spell the end of the longstanding Hispanic paradox in mortality (Goldman, 2016; Hummer & Hayward, 2015) to contribute new empirical knowledge necessary to assess and further contextualize this question by exploring three specific and interrelated lines of inquiry of great consequence to population health and policymaking efforts.

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Chapter 2 – Mexican Immigrant Health Advantage in Metabolic Syndrome? Decomposing the Effects of Demographic, Socioeconomic, and Health Behavior Characteristics

INTRODUCTION

A large body of research examines racial-ethnic and immigrant-native health disparities among the adult population in the United States (US). Studies indicate that minoritized racial-ethnic groups such as Blacks and Hispanics have worse health than the majority group of non-Hispanic whites (Brown, 2018). Research also documents an immigrant health advantage across various racial-ethnic backgrounds and areas of origin with immigrants experiencing better health, particularly within their first decade of relocation, and also outliving their native US-born peers (Antecol & Bedard, 2006; Brown, 2018; Hummer & Gutin, 2018). Hispanics also hold a puzzling yet persistent survival advantage over non-Hispanic whites, termed the *Hispanic paradox*, which is most pronounced among first-generation Mexican immigrants (Lariscy et al., 2015; Markides & Coreil, 1986; Markides & Eschbach, 2005).

Despite these consistently documented patterns, it is unclear whether recent waves of Mexican immigrants will continue to enjoy a health advantage in at least one key area, metabolic syndrome (MetS). MetS captures several markers of dysregulation—including obesity, elevated blood glucose levels, and hypertension—and is a strong predictor of morbidity and mortality (Alberti et al., 2009; Eckel et al., 2010). There are two key sources of concern about the future metabolic health of recent cohorts of Mexican immigrants to the US. First, Mexico's rapid nutrition and epidemiologic transitions have been followed by one of the steepest increases in obesity observed in any country (Popkin et al., 2012), with adult rates rising by 42.2% between 2000 and 2018 (Barquera et al., 2020). Second, a shift in Mexico-US immigration patterns and policy regimes has left recent waves of immigrants more vulnerable to the health deteriorating effects of heightened discrimination, hostility, and harsh work environments (Orrenius & Zavodny, 2009; Viruell-Fuentes et al., 2012).

Using nationally representative population health data, this study examines the metabolic health of foreign-born Mexicans, stratified by duration of residence in the US, relative to US-born Mexican Americans and non-Hispanic whites. I also further assess how key demographic, socioeconomic, and health behavior characteristics contribute to observed population health disparities. This study advances scholarship on racial-ethnic and immigrant-native health disparities, generally, and also specifically contributes new knowledge on the recent metabolic health of the US Mexican-origin population in two key ways. First, I leverage population level biomarker data to capture all the dimensions of MetS that have been linked to increased morbidity and mortality. Second, I focus on the role of social factors in population health disparities—including demographic, socioeconomic, and health behavior characteristics—to generate evidence that can help inform policy solutions. Generating a fuller understanding of how demographic, socioeconomic, and health behavior characteristics contribute to the recent patterning of metabolic health across groups defined by race-ethnicity, country of origin, and duration of residence can help researchers and policymakers identify preventive strategies to slow the rising risk of obesity and related metabolic conditions in the US and Mexico, and ultimately help preserve the prolonged life expectancy of Mexican immigrants and their descendants living in the US.

BACKGROUND

Racial-ethnic health disparities

Despite overall improvements in health and longevity over the past century, significant racial-ethnic health disparities rooted in social inequality persist and continue to present the greatest impediment to improving population health in the US (Gutin & Hummer, 2021; House, 2002). In racialized societies like the US (Bonilla-Silva, 1997), racism structures how minoritized groups, currently and historically, face differential access to resources, opportunities, and risks, making racism a fundamental cause of health and health disparities (Phelan & Link, 2015). Historically, the predominant focus of health disparities research in the US has been on Black-white health gaps, but disparities have also been increasingly documented between whites and Hispanics. Research in this area has emphasized Hispanics' survival advantage (Elo et al., 2004; Lariscy et al., 2015), but less attention has been dedicated to understanding whether the Hispanic paradox in mortality extends to other dimensions of health and wellbeing (Hayward et al., 2014). The existing research is mixed, suggesting that, compared to whites, Hispanics have similar or more favorable rates of cardiovascular disease and cancer (Crimmins et al., 2004), comparable or better psychological wellbeing (Williams, 2018), but higher rates of diabetes and disability (Crimmins et al., 2004; Hayward et al., 2014). These equivocal findings on the relative health standing of Hispanics are largely attributable to the complexity and heterogeneous patterns introduced by intersecting systems of discrimination and inequality by race, ethnicity, and immigrant status (Boen & Hummer, 2019).

Immigrant health advantage

Immigrants have lower mortality rates than US-born individuals (Dupre et al., 2012), less disability during their working years (Markides et al., 2007; Levchenko, 2021), and fewer chronic health conditions, including cancer, diabetes, heart disease, hypertension, and stroke (Brown, 2018; Gorman et al., 2010). In the US, this "immigrant health advantage" is particularly well-documented amongst the Mexican-origin population (Cho et al., 2004). Three explanations have been proposed to account for this healthy immigrant effect, including migrant selection, data issues, and differences in health behaviors and risk profiles.

First, immigrants are selected on numerous characteristics positively associated with health, and thus are generally healthier than the populations they leave behind and often those they are joining (Riosmena et al., 2013). The initial health advantage of the US immigrant population may also be partially reinforced by a pattern of return migration amongst migrants in poor health, commonly referred to as the "salmon bias" (Abraído-Lanza et al., 1999; Palloni & Arias, 2004). While positive selection on education and health have long characterized Mexican immigration to the US (Akresh, 2008), there are signs that this pattern is beginning to attenuate (Feliciano, 2005) and separate research also shows that return migration plays a limited role in observed health and mortality differences (Hummer et al., 2007; Riosmena et al., 2013; Turra & Elo, 2008).

A second explanation considers possible data issues that may disproportionately influence the health and mortality records of Hispanic immigrants, such as misidentification of ethnicity and age on death certificates and a higher probability of mismatched mortality records in population data sources. There is little empirical evidence that data issues account for a significant portion of Hispanic immigrant-native disparities (Hummer et al., 2007; Palloni &

Arias, 2004), although differential linkage of mortality records has been found to reduce the accuracy of mortality risk estimation for Hispanics in nationally-based US data sources (Lariscy, 2011). Finally, a third explanation focuses on differences in the health risk profiles of immigrants compared to the US native-born population, specifically less intensive and lower rates of smoking, lower rates of excessive drinking, and less obesity (Singh & Siahpush, 2002). Smoking behavior, in particular, has been shown to explain the majority of Mexican immigrants' health and mortality advantage over US-born whites (Blue & Fenelon, 2011; Fenelon, 2013). While all three of these explanations partially account for the health advantages previously observed among US Hispanic immigrants, it is also important to consider recent changes to the conditions immigrants experience in both sending and receiving countries to make sense of contemporary health patterns and to predict future trajectories.

Demographic, nutrition, and epidemiologic transitions and the rise of metabolic health risks in Mexico and the US

Over the past two decades Mexico has experienced significant demographic, nutrition, and epidemiologic transitions (Rivera et al., 2004). While all three transitions are interrelated, the demographic transition has been marked by lowered risk of premature mortality and population aging, the nutritional transition by a shift from prevalent undernutrition to a predominance of diet-related chronic conditions, and the epidemiologic transition by chronic conditions replacing infectious disease as the primary source of premature morbidity and mortality (Omran, 1971; Popkin, 2001). The drivers of evolving population dynamics in Mexico are multifactorial, but the influence of globalization and trade liberalization, such as the passing of the North American Free Trade Agreement (NAFTA) in 1992, has played an outsized role in weakening the power and viability of domestic food suppliers and yielding a food environment dominated by cheap and abundant processed foods (Thow, 2009). This drastic overhaul of the country's domestic food environment helped lay the groundwork for the rapid increase in obesity and related metabolic conditions that Mexico has experienced over the past two decades (Barquera & Rivera, 2020).

For much of the early 21st century, the US had the highest recorded adult obesity prevalence among OECD countries. Yet following these rapid nutrition and epidemiologic transitions, adult obesity in Mexico rose quickly and slightly surpassed that of the US in 2013 (Barquera & Rivera, 2020). The US has since reclaimed the top ranking, although the proportion of adults with severe obesity and the associated mortality risks remain higher in Mexico (Barquera et al., 2020; Monteverde et al., 2010; Ogden et al., 2020). Within the US, a similar dynamic exists with Hispanics, and Mexican Americans in particular, exhibiting a higher obesity prevalence than whites (Flegal et al., 2012; Flegal et al., 2016). In both countries today, the main causes of preventable mortality are associated with obesity, including cardiovascular disease, diabetes, chronic respiratory disease, and cancer (WHO, 2018a; WHO, 2018b). This convergence in the nutritional and epidemiologic profiles of Mexico and the United States raises important questions about whether recent and future generations of Mexican immigrants will continue to hold a metabolic health advantage over the US-born population (Goldman, 2016), with some evidence suggesting that this advantage has already begun to deteriorate among youth-aged Mexican immigrants in California (Buttenheim et al., 2013).

Social determinants of immigrant health deterioration

Immigrants' health tends to decline shortly after migration (Goldman et al., 2014), with evidence that initial health advantages erode significantly and can even disappear altogether within the first decade of relocation (Antecol & Bedard, 2006). One prominent explanation points to the detrimental effects of acculturation on immigrant health behaviors through exposure to US society, which has been supported as a leading explanation for the "disability crossover" (Levchenko, 2021), whereby Mexican immigrants with an initial age-specific disability advantage in their working years later have higher rates of disability relative to US-born whites at older ages regardless of educational achievement (Levchenko, 2021). However, more nuanced explanations have also been offered, guided by segmented assimilation theory and related frameworks from the immigrant integration literature (Portes & Zhou, 1993). These explanations recognize both immigrants' acculturation to American preferences and norms and also the existence of segmented pathways to immigrant inclusion based on socioeconomic position and mobility (Goldman et al., 2014; Van Hook et al., 2016). Thus, while the majority of Mexican immigrants facing socioeconomic disadvantage might be expected to acculturate to the less healthy behaviors of lower-income groups in the US (Abraído-Lanza et al., 2006), others will incorporate into more advantaged positions where they may encounter health promoting behaviors and opportunities. Consistent with this framework of multiple acculturative processes, research comparing Mexican migrants to non-migrants remaining in Mexico shows that those who migrate are more likely to experience significant short-term changes in health, whether positive or negative, with an overall trend towards health deterioration for the majority of recent Mexican immigrants (Goldman et al., 2014). However, evidence consistent with various acculturative processes does not rule out the possibility that discrimination and other structural forces may be operating simultaneously to influence patterns of immigrant health deterioration regardless of socioeconomic standing and level of integration into US society (Levchenko, 2021). Thus, others have also focused on social inequality as a root cause of immigrant health declines, acknowledging that Mexican immigrants across the socioeconomic spectrum may face varying levels of discrimination and chronic stress due to how they are perceived and treated within US society (Viruell-Fuentes et al., 2012). Taken together, it is clear that research on racial-ethnic and nativity health disparities must consider not only the effect of exposure to US society on immigrant health and health behaviors, but also the contribution of social factors and structural environments that play a role in shaping immigrants' experiences and opportunities post-migration.

Research aims

In light of uncertainty over the current and future metabolic health of the Mexican-origin population in the US, I pursue two aims in the present study:

1. Compare the metabolic profiles of adult-aged US-born whites, US-born Mexican Americans, and recent and earlier Mexican immigrants to evaluate whether recent Mexican immigrants hold a metabolic health advantage.
2. Assess the contribution of demographic, socioeconomic, and health behavior characteristics to observed population health gaps by race-ethnicity, country of origin, and duration of residence in the US.

MATERIALS AND METHODS

Data and sample

Data were acquired from the National Health and Nutrition Examination Survey (NHANES), a cross-sectional, nationally representative, population-based survey conducted by the Centers for Disease Control and Prevention that uses a complex, multistage probability sampling strategy designed to be representative of the civilian, non-institutionalized US population (NCHS, 2013; NCHS, 2018). I combined eight waves of data (1999–2016) for adults aged 20 or older. I excluded respondents who were pregnant (n = 1,029), did not complete the physical examination (n = 1,480), were not included in the morning laboratory examination that was restricted to the fasting subsample (n=16,076) or had their age top-coded in NHANES (n = 790), leaving an eligible sample of 11,559 individuals. The sample was further restricted to those with complete information on all study outcomes, creating a final analytic sample of 10,833 individuals (93.7% of eligible sample): foreign-born Mexican (n = 1,799), US-born Mexican American (n = 1,334), US-born non-Hispanic white (n = 7,700).

Measures

Metabolic syndrome (MetS) was the primary outcome. I constructed the MetS measure using the six individual risk factors included in the most recently harmonized definition of MetS (Alberti et al., 2009). MetS encapsulates several health conditions that epidemiological studies have found to co-occur in patients with a high risk of cardiovascular disease and type-2 diabetes. The six indicators of metabolic dysregulation include: elevated fasting glucose (≥ 100 mg/dL), elevated triglycerides (≥ 150 mg/dL), lowered HDL cholesterol (< 40 mg/dL for males, <50 mg/dL for females), elevated blood pressure (systolic ≥ 130 mmHg, diastolic ≥ 85 mmHg), obesity (BMI ≥ 30 kg/m^2), and an increased waistline (≥ 102 cm for males, ≥ 88 cm for females) (Alberti et al., 2009; Eckel et al., 2005). Respondents were classified as having MetS if they possessed three or more of the individual health risks based on NHANES laboratory and physical examinations, or self-reported taking medications to control them (Alberti et al., 2009; Eckel et al., 2005). I created dichotomous measures (0/1) for each component as well as a summary indicator of MetS (0/1).

I divided the sample into four groups to examine differences in MetS by race-ethnicity, country of origin, and duration of residence in the US. The two US-born groups, non-Hispanic whites (hereafter, US-born whites) and Mexican Americans, were each defined based on self-reported responses to a single race-ethnicity question. In order to analyze expected changes in health status with increasing time spent in the US, I sub-classified the foreign-born Mexicans (Mexican immigrants) into two additional groups (recent and earlier immigrants) based on their self-reported duration of residence in the US: less than ten years (n = 493), or ten years or more (n = 1,250).

Three categories of independent variables were used to explain prevalence differences in MetS: demographic characteristics, socioeconomic factors, and health behaviors. Demographic characteristics included age and gender. Socioeconomic factors included education (less than high school, high school or GED, and some college/college graduate), employment (not employed, part-time under 35 hours/week, and full-time over 35 hours/week), and income (income-to poverty ratio). Given the cross-sectional nature of the data, I selected three health behaviors that would be difficult for respondents to alter in response to a diagnosis of MetS in effort to minimize reverse causation bias. These included three-category measures of alcohol consumption (never or former drinker, moderate drinker [≤ 1 drink/day for females, ≤ 2 drinks/day for males], and heavy or binge drinker [> 1 drink/day for females, > 2 drinks/day for males]) and food security (full, marginal, and low/very low), as well as a continuous measure of years spent smoking. I also included a survey wave indicator in all analyses to adjust for trends in MetS over the study period.

Analysis

All analyses were weighted and conducted in Stata/MP-2 17.0 using the `svy` command prefix (StataCorp, College Station, Texas, USA). Within the analytic sample, 15.3% had missing data on one or more covariates (education, employment, income-to-poverty ratio, years smoking, alcohol, and/or food security), with no more than 6.3% of the sample missing on any single covariate. In order to preserve cases and to avoid introducing bias through listwise deletion (Allison, 2001), I employed multiple imputation separately for each study population. I estimated unadjusted proportions and means for all demographic, socioeconomic, and health behavior characteristics, as well as all metabolic health outcomes. To account for major differences in the age structure of each of the four study populations, I then estimated 18-year age-standardized prevalence rates using direct standardization to the 2000 US Census population age distribution (Klein & Schoenborn, 2001). I also determined the prevalence rate for each study group at every two-year survey wave, and then imposed a GLM smoothing function to graph the group trends in MetS over the full study period.

For the main analysis, I decomposed the MetS prevalence difference between US-born whites and recent Mexican immigrants, in order to assess how key demographic, socioeconomic, and health behavior characteristics contribute to a possible immigrant health advantage. The decomposition divides between-group differences in the dependent variable into a component due to differences in population characteristics (i.e., the “explained” or “endowment” portion) and a component due to differential returns to those characteristics (i.e., the “unexplained” or “coefficient” portion). The unexplained portion represents the between group disparity that would theoretically remain if the two groups were matched on identical levels for all model variables. This technique—first introduced by sociologist and demographer Kitagawa (Kitagawa, 1955), and further popularized by economists Blinder and Oaxaca (Blinder, 1973; Oaxaca, 1973)—has been increasingly recognized as a preferred approach for analyzing and explaining racial-ethnic disparities in health (Jackson & VanderWeele, 2018; VanderWeele & Robinson, 2014). An age^2 term was also included to account for the curvilinear association between age and MetS.

I subsequently estimated associations between independent variables and MetS in each study population using Poisson regression with a log link function and robust standard errors to directly estimate the prevalence rate ratio (PRR) between groups (Barros & Hirakata, 2003). This model also included interactions of gender x race-ethnicity/country of origin/duration of residence group and education x race-ethnicity/country of origin/duration of residence group to account for expected differences in associations by study population. An age^2 term was also included in the regression model. I then estimated the predicted prevalence of MetS associated with a specified value of each covariate with age held at the overall sample mean (46.5), and all other covariates fixed at their observed levels for each individual and then averaged within each group. All tests were two-sided and significance was considered at $P < 0.05$ for all analyses.

RESULTS

Descriptive statistics

Table 2-1 summarizes the weighted demographic, socioeconomic, and health behavior characteristics, of the four study groups. Recent Mexican immigrants were the youngest group, with a mean age of 32.2 years for those residing in the US less than ten years. Mexican immigrants residing in the US for ten years or more were closer in age to US-born Mexican Americans, with mean ages for these groups of 42.1 and 40.2 years, respectively. US-born whites were the oldest population, with a mean age of 47.2 years. Both groups of foreign-born Mexicans were composed of more males compared to US-born Mexican Americans and US-born whites. Both groups of foreign-born Mexicans had significantly lower educational attainment and income, but had higher levels of full-time employment than US-born groups. In terms of health behaviors, both the US-born and foreign-born Mexicans had smoked fewer years than US-born whites on average. The foreign-born Mexican groups had the highest share of non- and former-drinkers, but also the highest levels of heavy alcohol drinkers, while US-born whites and Mexican Americans had higher shares of moderate drinkers. US-born whites were the most food secure of all the groups, with significantly higher levels of full food security and the lowest levels of food insecurity (i.e., low/very low food security), while both groups of foreign-born Mexicans had lower levels of food security and higher levels of food insecurity relative to the US-born groups.

Table 2-1 also presents the unadjusted and age-standardized health outcomes by study group. Prior to age-standardization, recent Mexican immigrants hold a clear and significant advantage in metabolic health, with lower prevalence rates of low HDL cholesterol, high blood pressure, high waist circumference, obesity, and MetS overall as compared to the other three groups. US-born Mexican Americans and foreign-born Mexicans residing in the US for ten years or more had the highest unadjusted prevalence rates of MetS overall, along with high levels of many of the individual high-risk metabolic health indicators. Upon standardizing all of the study groups to the 2000 US Census age distribution, the recent immigrant health advantage in MetS over US-born whites disappears. However, a significant advantage remains for recent Mexican immigrants over earlier Mexican immigrants and US-born Mexican Americans. Figure 2-1 portrays these age-standardized trends in MetS over the eighteen-year study period, with recent Mexican immigrants and US-born whites holding lower prevalence rates of MetS at the beginning of the period, but a less distinct advantage over the other two groups by the end of the period. This figure also reveals that both US-born groups held trajectories of increasing MetS prevalence over the study period, while both groups of Mexican immigrants are seen to follow relatively flat overall trends.

Decomposition

The results of the decomposition analysis are summarized in Figure 2-2. Panel A depicts the unadjusted MetS prevalence rates for US-born whites (45.5%) and recent Mexican immigrants (29.5%), as well the prevalence difference between the two groups (16.0%). The explained portion in Panel A indicates that nearly 40% of the prevalence difference (i.e., 6.1 prevalence points) would be eliminated if associations were causal and the two groups had the same mean level on all model variables. Conversely, the remaining ~60% of the gap (9.9 prevalence points) would theoretically remain under these same conditions. Panel B summarizes the contribution of each study variable to the explained portion of the MetS prevalence difference between US-born whites and recent Mexican immigrants. While the full prevalence difference is accounted for by the younger age structure of recent Mexican immigrants as compared to US-born whites (i.e., statistically-explaining 17.4 prevalence points), this group would retain a sizable metabolic health advantage of roughly 11.6 prevalence points, even after adjusting for age differences, if they were to achieve parity with US-born whites on education (3.2 prevalence points), income levels (4.5 prevalence points), drinking behavior (0.7 prevalence points), and levels of food security (3.2 prevalence points).

Multivariate and predictive models

Figure 2-3 presents the predicted prevalence rate of MetS associated with specified levels of the three social factors found to have the greatest potential to improve recent Mexican immigrants' metabolic health: education, income, and food security. Consistent with the results of the decomposition, recent Mexican immigrants are shown to retain a metabolic health advantage over US-born whites when both groups are assigned the same fixed level on each of these measures. Of note, while US-born Mexican Americans and foreign-born Mexicans residing in the US for ten or more years also receive relative improvements in their metabolic health risk from increasing education, income, and food security, these gains are not sufficient to overcome their metabolic health disadvantage relative to US-born whites and recent Mexican immigrants. The underlying Poisson regression model from which the predicted prevalence rates were derived is summarized in Appendix Table A-1 and the full set of predicted prevalence rates associated with all study measures is summarized in Appendix Table A-2.

DISCUSSION

In this paper I first aimed to determine whether the Hispanic advantage in mortality extends to a lower risk of the major chronic conditions which constitute metabolic syndrome among recent Mexican immigrants to the US. I find that recent Mexican immigrants do exhibit an overall metabolic health advantage, which is largely attributed to their younger age structure compared to earlier Mexican immigrants, US-born Mexican Americans, and US-born whites. I then explored how key demographic, socioeconomic, and health behavior characteristics contribute to the prevalence of MetS among foreign-born and US-born Mexican Americans relative to US-born whites. The insights from this analysis advance our knowledge of how key characteristics relate to the metabolic health of Mexican immigrants and illuminate areas of policy intervention that may help to preserve their health, and that of their descendants, with increasing time spent in the United States.

A small number of nationally-representative studies have previously explored whether the Hispanic advantage in mortality extends to a lower risk of the major chronic conditions which constitute MetS and related syndromes (Boen & Hummer, 2019; Crimmins et al., 2007; Zhang et al., 2012), all reporting no significant Hispanic metabolic health advantage after adjusting for basic demographic factors, such as age, gender, and/or marital status. Yet given sample size and data constraints, each of these earlier studies was prevented from further stratifying by country of origin and duration of residence, which are notable limitations given that foreign-born Mexicans residing in the US for less than a decade typically hold the greatest overall health and mortality advantages (Antecol & Bedard, 2006; Markides & Eschbach, 2005). The present study improves on these limitations, yet reaches a similar conclusion, as I found that the full prevalence difference in MetS between recent Mexican immigrants and US-born whites was more than accounted for by the immigrants' younger age structure. However, my results also reveal that recent Mexican immigrants would retain a sizable metabolic health advantage, regardless of age structure, if they were to achieve parity with US-born whites in terms of educational attainment, income levels, and food security. This finding aligns with prior research suggesting that Hispanics' mortality levels would be even more favorable if not for their socioeconomic disadvantage (Lariscy et al., 2015). Additionally, though not sufficient to overcome their significant metabolic health disadvantage, US-born Mexican Americans and earlier Mexican immigrants were also predicted to see relative improvements in their MetS risk from higher levels of education, income, and food security. These results highlight the need to take a preventive, social determinants focused approach in supporting newly-arrived immigrants in maintaining their health upon migrating to the US.

Policy solutions are needed to help resolve many of the socioeconomic inequalities immigrants face. The results of this study support focusing on policies that would help to resolve immigrant-native disparities in income, food security, and education, such as equitable pathways to citizenship and robust worker protections. A path to citizenship has already been proposed for undocumented agricultural workers under the House-approved, Senate-pending Farm Workforce Modernization Act of 2021 (H.R.1603) (Lofgren, 2021). Additional legislation could also help to ensure all undocumented workers, whose labor currently upholds multiple sectors of the US economy, are able to receive livable wages, safe and humane work and living conditions, and robust enforcement of these protections. Short of providing a pathway to citizenship and extending additional protections for migrant workers, both the food insecurity and immediate financial precarity faced by newly-arrived immigrants could be partially addressed by de-coupling the eligibility for federal and state-based welfare programs—such as SNAP benefits, housing assistance, disability and unemployment, Medicaid, and SSI—from documentation status, especially since undocumented immigrants already pay billions of dollars into these programs annually (Southern Poverty Law Center, 2010). The expected impact on metabolic health from this proposed shift in policy is further supported by recent research showing that unauthorized Hispanic immigrants face significantly heightened risks of weight gain and obesity with time spent in the US relative to their co-ethnic peers who hold legal residence status (Altman & Bachmeier, 2021).

Improving the educational attainment of adult immigrants will likely prove difficult under any policy regime, but opportunities to pursue higher education should be safeguarded and expanded for those who migrate as children or teenagers. While young immigrants are currently able to seek protections under the Deferred Action for Childhood Arrivals (DACA) policy, as a temporary work permit program, DACA has been shown to present barriers to higher education by incentivizing work over educational investment (Hsin & Ortega, 2018). In a recent session of Congress the House approved the American Dream and Progress Act of 2019 before it stalled in the Senate, which would have offered young immigrants permanent legal status (H.R.6) (Roybal-Allard, 2019). The passage of this more expansive legislation would be expected to have a significant impact on reducing barriers to educational attainment for young immigrants (Francesc et al., 2019). The findings of the current study suggest that policy solutions are needed to address socioeconomic inequality and support immigrant health, and a variety of recent legislative efforts have been aligned with this goal; what is needed now is the political will to pass them.

While this study offers significant contributions to the current literature on the health of Mexican immigrants to the US, it also presents limitations. First, this study faces a number of possible selection issues. Given that I do not have access to data from the counterfactual population of Mexicans who did not migrate to the US, I cannot assess healthy migrant selection effects as part of the explanation for recent Mexican immigrants' initial metabolic health advantage relative to the other groups in the sample. This is notable since other researchers able to combine data from NHANES (1999–2010) with data from the Mexican National Health and Nutrition Survey (2006) have found evidence of a modest migrant selection effect contributing to foreign-born Mexicans' metabolic health advantage relative to non-Hispanic whites (Beltrán-Sánchez et al., 2016). Related to this, I also cannot rule out the presence of selection bias into the NHANES sample, as it is possible that immigrants selected and willing to respond may differ in systematic and consequential ways from those not selected or not willing to respond to survey administrators. However, even in the presence of unmeasured migrant selection effects, the results presented offer valuable insight into key factors that influence the health of those who did migrate and now reside in the US.

The second area of limitation relates to the cross-sectional nature of the data source, which prevents causal conclusions from being drawn from this analysis. In attempt to minimize likely sources of reverse causation bias, I included measures that would be difficult for respondents to alter in response to a change in health status or diagnosis. However, this precaution also prevented me from including certain measures known to have strong associations with metabolic health, such as dietary intake and physical activity, which may have introduced possible omitted variable bias. The cross-sectional nature of the data also prevented me from directly assessing how the metabolic health of the immigrants in the sample might be affected by the accumulated stresses and opportunities encountered through the process of migration and acculturation. Finally, given the limited sample of foreign-born Mexicans, I was unable to model outcomes separately for each gender.

CONCLUSION

This study fills a critical gap in our knowledge of how key social and behavioral characteristics influence the metabolic health of first- and later-generation Mexican immigrants, at a time when the prevalence of major chronic metabolic conditions like obesity and diabetes are continuing to rise in both Mexico and the United States. To ensure that newly-arrived Mexican immigrants and their descendants continue to enjoy historically-documented health and mortality advantages in the future, modest changes in US immigration and social policy could help to offer health-promoting protections in the form of increased economic and food security, as well as improved educational opportunities for younger immigrants.

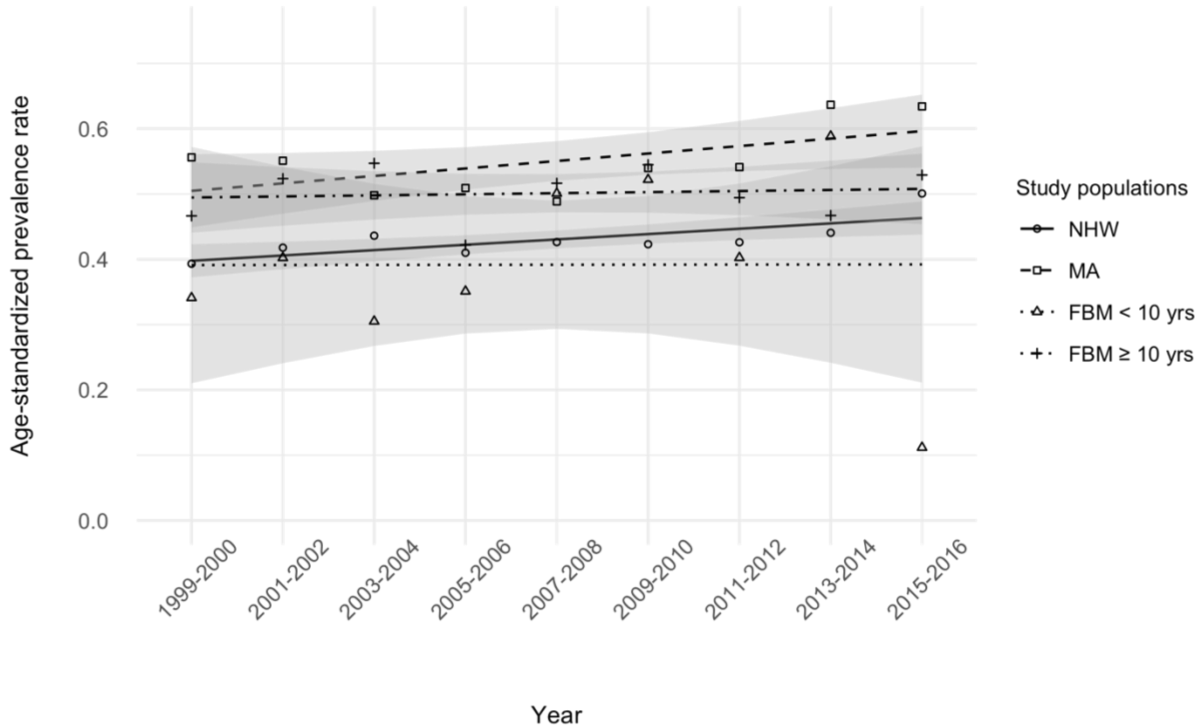
Table 2-1. Weighted demographic, socioeconomic, health behavior characteristics, and outcomes by race-ethnicity, country of origin, and duration of residence

	US-born		Foreign-born Mexicans (FBM)	
	Non-Hispanic whites (NHW) (*N* = 7,700)	Mexican Americans (MA) (*N* = 1,334)	In US < 10 years (*N* = 491)	In US 10+ years (*N* = 1,308)
Demographic characteristics				
Age, [mean (SE)]	47.2†‡§ (0.277)	40.2*‡§ (0.462)	32.2*†§ (0.552)	42.1*†‡ (0.553)
Gender, male [%]	49.9‡§	50.9‡§	59.1*†	54.9*†
Socioeconomic characteristics				
Education [%]				
Less than high school	11.7†‡§	24.1*‡§	66.5*†	67.5*†
High school or GED	24.5§	24.1§	20.7	16.4*†
Some college or college graduate	63.7†‡§	51.8*‡§	12.8*†	16.2*†
Income-to-poverty ratio (PIR), [mean (SE)]	3.3†‡§ (0.044)	2.5*‡§ (0.085)	1.3*†§ (0.064)	1.6*†‡ (0.048)
Employment [%]				
Not employed	32.3‡	31.6‡	24.8*†	29.0
Part time (1-34 h/week)	14.3	14.5	13.3	12.8
Full time (≥ 35 h/week)	53.4‡§	53.9‡	61.9*†	58.2*
Health behaviors				
Smoking, years spent [mean (SE)]	10.7†‡§ (0.257)	6.8*‡ (0.371)	4.8*†§ (0.428)	6.5*‡ (0.383)
Alcohol [%]				
Never or former drinker	23.7‡§	25.3§	30.8*	35.7*†
Current moderate drinker	38.8†‡§	26.1*‡§	19.2*†	20.4*†
Current heavy or binge drinker	37.5†‡§	48.6*	50.0*	43.8*
Food security [%]				
Full food security	85.4†‡§	65.7*‡§	45.1*†§	53.6*†‡
Marginal food security	5.4†‡§	15.1*‡	23.5*†§	17.5*‡
Low/very low food security	9.2†‡§	19.2*‡§	31.4*†§	28.9*†
Outcomes, unadjusted 18-year prevalence				
High-risk metabolic health indicators [%]				
Pre-diabetes	43.2§	44.8§	41.9§	55.5*†‡
High triglycerides	29.5§	31.5	29.2	34.4*
Low HDL cholesterol	40.3‡	41.6‡	34.4*†§	40.7‡
High blood pressure	38.5†‡§	32.0*‡§	13.2*†§	26.5*†‡
High waist circumference	54.6†‡	60.8*‡§	36.9*†§	54.8†‡

Obesity	33.5†‡§	45.5†‡§	23.2*†§	39.8†‡§
Metabolic syndrome, ≥ 3 high-risk health indicators	45.5†‡	50.9*‡	29.5*†§	49.6‡
Outcomes, age-standardized 18-year prevalence[a]				
High-risk metabolic health indicators [%]				
Pre-diabetes	40.5†‡§	49.8*§	50.7*§	56.9*†‡
High triglycerides	28.6†‡§	33.7*	37.6*	34.3*
Low HDL cholesterol	39.0†§	43.2*	38.2	42.3*
High blood pressure	34.9†‡§	38.5*‡§	28.8*†	30.8*†
High waist circumference	52.6†	63.5*‡§	50.7†	55.5†
Obesity	32.7†‡§	46.2*‡§	28.1*†§	40.1*†‡
Metabolic syndrome, ≥ 3 high-risk health indicators	42.9†§	55.4*‡§	43.0†§	50.7*†‡

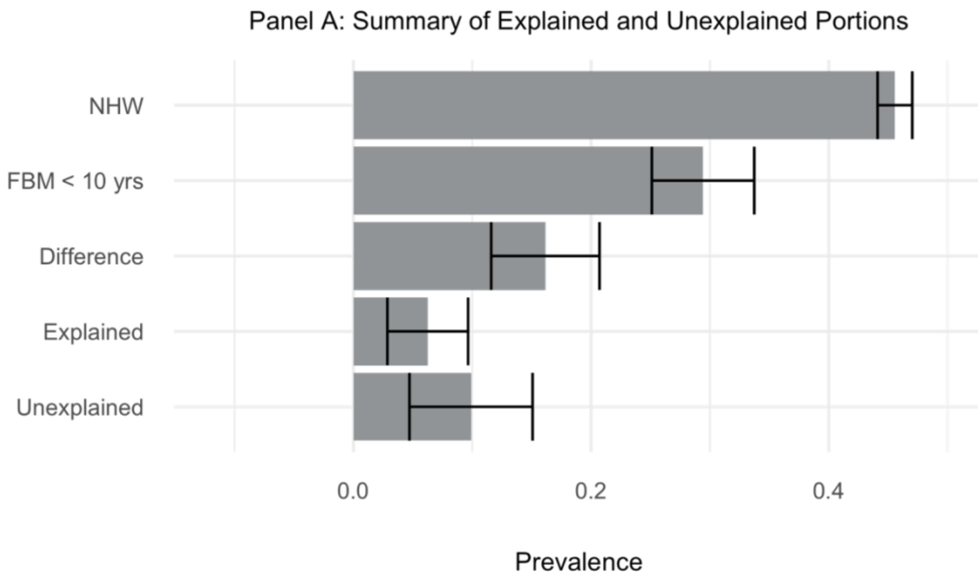
Notes. Weighted descriptive statistics. Symbols indicate a statistically significant difference at the $\alpha = 0.05$ level in proportions/means between the respective group in each column and US-born non-Hispanic whites (*), US-born Mexican Americans (†), foreign-born Mexicans in the US < 10 years (‡), and foreign-born Mexicans in the US 10 or more years (§).
[a] Prevalence rates for the eighteen-year study period are age-standardized to the US population distribution according to the 2000 US Census and incorporate survey weights to generate nationally representative estimates.

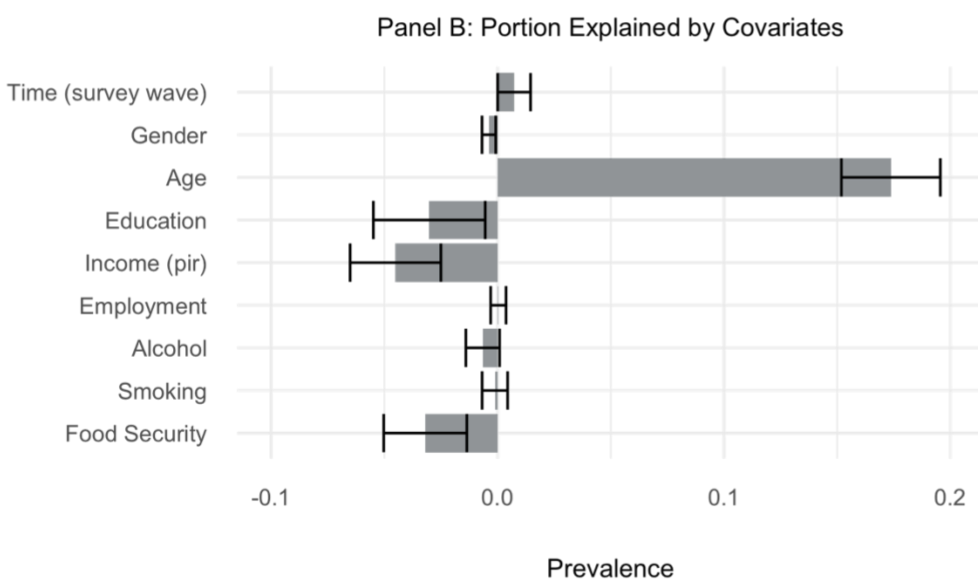
Figure 2-1. Age-standardized metabolic syndrome (MetS) prevalence by race-ethnicity, country of origin, and duration of residence



Notes. Prevalence rates for each two-year study period (presented as point estimates) are age-standardized to the US population distribution according to the 2000 US Census and incorporate survey weights to generate nationally representative estimates. A GLM smoothing function is applied to overlay the trends in metabolic syndrome for each group over the eighteen-year study period. The study populations are abbreviated as follows: US-born non-Hispanic whites (NHW), US-born Mexican Americans (MA), foreign-born Mexicans residing in the US for less than ten years (FBM < 10 yrs), and foreign-born Mexicans residing in the US for ten years or more (FBM ≥ 10 yrs).

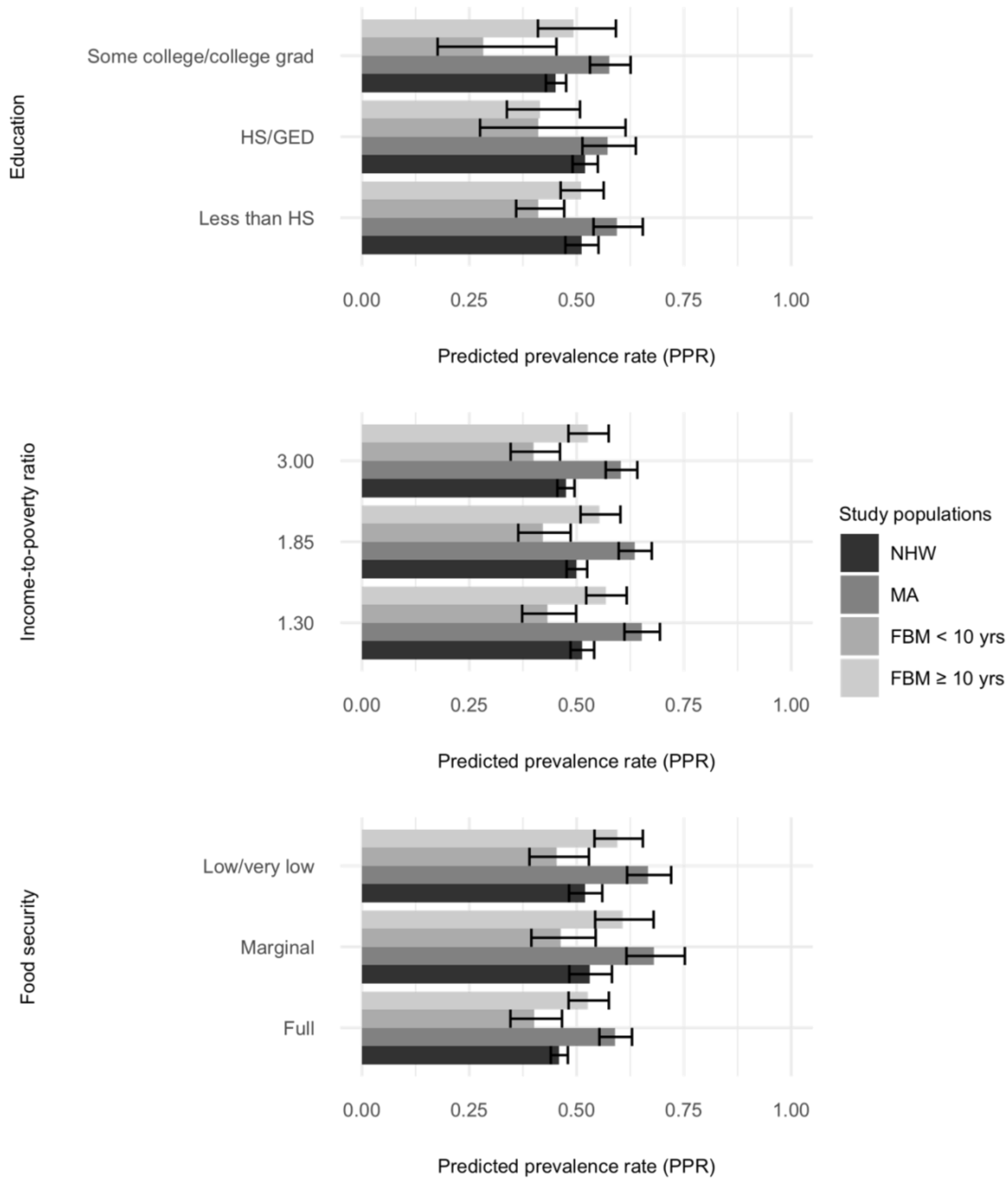
Figure 2-2. Decomposition of the prevalence difference in metabolic syndrome (MetS) between US-born non-Hispanic whites and foreign-born Mexicans residing in the US < 10 years





Notes. Panel A summarizes the explained and unexplained portions of a two-way, logistic regression-based Oaxaca-Blinder decomposition of the prevalence difference in metabolic syndrome between non-Hispanic whites (NHW) and recent Mexican immigrants (FBM < 10 yrs). Panel B portrays the individual contribution of each study variable to the explained portion of the decomposition.

Figure 2-3. Predicted prevalence rates of metabolic syndrome (MetS) associated with select demographic, socioeconomic, and health behavior characteristics by race-ethnicity, country of origin, and duration of residence



Notes. Predicted prevalence rate (PPR) associated with key independent variables (holding age at the sample mean of 46.5 and all other covariates at their observed levels for each individual) by race-ethnicity/country of origin/duration of residence group. Predicted rates are based on an underlying Poisson regression model with a log link function and robust standard errors, used to directly estimate the prevalence rate ratio between groups.

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Chapter 3 – Erosion of the Hispanic Paradox? Projecting the Effects of Obesity on Future Life Expectancy in the US

INTRODUCTION

Hispanics in the United States (US) have held a documented life expectancy advantage over non-Hispanic whites for nearly three decades, an advantage that has been particularly pronounced among foreign-born Hispanics (Cho et al., 2004; Hummer et al., 2000; Lariscy et al., 2016; Markides & Coreil, 1986). For example, prior to the COVID-19 pandemic, US-born Hispanic adults were expected to live two years longer than non-Hispanic white adults on average, while the favorable gap in life expectancy extended to between three and four years for foreign-born Hispanics (Frisco et al., 2019). Yet this longevity advantage is difficult to reconcile against the socio-economic disadvantages faced by Hispanics, in terms of income and educational attainment, relative to the rest of the US population (Gonzalez-Barrera & Lopez, 2013). The literature has consistently documented a strong and positive socioeconomic-health gradient that persists across all levels of socioeconomic status (Adler et al., 1994; Adler & Ostrove, 1999) and which endures as a fundamental cause of health for all racial-ethnic groups aside from first-generation immigrants (Link & Phelan, 1995). Hispanics' contradictory mortality advantage over non-Hispanic whites has come to be known as the *Hispanic paradox* (Markides and Coreil 1986).

Although the Hispanic paradox has persisted for decades, and has held up as more than a data artifact (Hummer et al., 2007; Turra & Elo, 2008), there is cause to question whether young

Hispanics in the US today will continue to live longer than the rest of the population. Hispanics now have one of the highest prevalence levels of obesity compared to other racial-ethnic groups in the United States, and this trend is most concentrated amongst young second- and later-generation US-born Hispanics (Akresh, 2008; Barcenas et al., 2007; Kaplan et al., 2004; McTigue et al., 2002). This trend has led some researchers to question whether the rise in obesity, and heightened susceptibility to major metabolic health risks such as diabetes and cardiovascular disease, could erode their longstanding longevity advantage (Goldman, 2016; Hummer & Hayward, 2015).

In this study, I estimate the effect of increasing obesity on adult mortality in the United States over the period 2015–2045 to better understand how the mortality burden of rising obesity may reshape longstanding mortality patterns across US racial-ethnic and nativity groups, and specifically, what these trends imply about the future persistence of the Hispanic mortality advantage. I closely follow the analytic approach developed by Preston, Stokes, Mehta, and Cao (2014) as the basis for the obesity projections, adapting the modeling approaches and bringing in additional data sources as necessary to permit estimation of future obesity levels and associated effects on mortality across the three racial-ethnic and nativity groups of interest: US-born non-Hispanic whites (hereafter, US-born whites), US-born Hispanics, and foreign-born Hispanics. As with the earlier paper, I incorporate information about cohorts' weight histories, allowing the estimated effects on mortality to cumulatively reflect both current and early adulthood weight status. Prior research has demonstrated the importance of accounting for historical weight, in addition to baseline weight, to fully capture the potential mortality impacts of obesity (Abdullah et al., 2011; Preston et al., 2013; Stokes & Preston, 2016). To my knowledge, this paper is the first to use formal demographic projection techniques to estimate how widening racial-ethnic/nativity disparities in obesity prevalence and intensity could impact the future of the Hispanic paradox among the current US adult population.

BACKGROUND

Obesity and mortality

The prevalence of obesity and mean levels of BMI among the US adult population have been rising consistently since 1980 (Wang et al., 2020). While all sociodemographic groups have experienced significant increases in body weight over the past three decades, the trend has been particularly pronounced for Hispanics relative to non-Hispanics. According to a recent report based on measured height and weight data in a nationally-representative survey sample from 2017-2018, the age-adjusted population prevalence of obesity for Hispanics was 44.8% versus 42.2% for non-Hispanic whites (Hales et al., 2020). Notably, this ethnic disparity in obesity has historically been considerably wider, with the latest estimate representing a narrowing of 58% just since 2013-2014 (Flegal et al., 2016). This may suggest that the once stark weight disparities between racial-ethnic groups could continue to narrow if there is a convergence towards some upper ceiling of overweight and obesity levels for all groups. These broad-based population trends have placed an enormous burden on individuals, households, the labor market, and US society as a whole, with overweight and obesity now annually accounting for 300,000 preventable deaths, netting direct health care costs of $480.7 billion, and contributing to an additional $1.24 trillion in indirect costs due to lost economic productivity (Waters and Graf, 2020). Given this, projecting a clear picture of future obesity levels, and estimating how those projections will impact future mortality patterns in the US population, is of great importance to multiple sectors of US society and policy planning efforts.

It is clear that obesity presents a significant mortality risk, yet pinning down the true magnitude of the effect—particularly across BMI categories, for various age and sociodemographic groups, over different time periods, and across data sources and identification strategies—has proven a complex and somewhat controversial endeavor. Yet it is a task of great importance, as the reliability of any population-level projection of how obesity could impact future life expectancy relies heavily on the accuracy of individual-level estimates of the relative risk of mortality across BMI categories in that population (Mehta & Chang, 2011a). The peak of the controversy surrounding the estimation of obesity-attributable mortality arose amidst a well-publicized and contentious dispute surrounding two papers (Flegal, 2021); the first attributed high levels of mortality to overweight and class I obesity (Mokdad et al., 2004), while the second concluded that overweight may actually be protective against mortality, with significant elevations in mortality risk only detected for the highest classes (II/III+) of obesity (Flegal, 2021). The divergence between these two studies can be sourced to controversies surrounding specific methodological decisions made in the first paper by Mokdad et al. (2004), which has yielded some key lessons to produce more accurate estimates of individual-level obesity risks in future studies, namely: accounting for effect modification by age; controlling for smoking behavior and considering exclusions for individuals with pre-existing diseases that have a strong causal link to smoking; taking care to avoid under-controlling for socioeconomic status; and using the latest available data given evidence of a secular decline in the mortality effects of obesity (Mehta & Chang, 2011b, 2011a).

Obesity as a threat to the Hispanic paradox in mortality

As early as 2016, researchers have been asking whether Hispanics' high rates of obesity and heightened vulnerability to diabetes, disability, inflammation, and related metabolic health problems could begin to erode their long-standing life expectancy advantage (Goldman, 2016). The salience of this question has only increased in recent years, as population-wide reductions in smoking behavior over the past few decades have brought the smoking rates of whites down much closer to the rates of Hispanics (Bostean et al., 2017). This previous disparity advantaging Hispanics in a key health behavior linked to preventable mortality once served as a leading explanation for their life expectancy advantage (Blue & Fenelon, 2011; Fenelon, 2013; Lariscy et al., 2015). Given this shift, at least one of two things would need to be true for obesity to threaten the future of the Hispanic mortality advantage over the next few decades. One would be if future trends in obesity prevalence for Hispanics continue to outpace those of whites, and the second would be if Hispanics faced an elevated mortality burden from obesity as compared to whites.

As discussed above, the once stark ethnic disparity in obesity prevalence between whites and Hispanics has narrowed considerably in recent years, and while less is known about differential obesity-related mortality risks by race-ethnicity/nativity, the current evidence is mixed. Two studies have found that, despite their higher prevalence of obesity and related co-morbidities, Hispanics face lower obesity-related mortality risks as compared to whites (Daw, 2017; de Cosio et al., 2021), while one other has reported that the mortality risk faced by Hispanics is significantly higher (Van Hook et al., 2020). The latter paper, notably, represents the only empirical study to date that has directly explored how obesity might affect the future of the Hispanic paradox, and thus offers a valuable point of comparison to this current study. The authors employed a novel cross-sectional multiple imputation technique to supplement a nationally representative health survey containing a large study sample (i.e, the National Health

Interview Study (NHIS)) with examination-based height/weight data from a similarly focused, but much smaller study sample (i.e., the National Health Examination Study (NHANES)). With the large, imputed dataset, the authors used a counterfactual modeling approach to assign each racial-ethnic/nativity group, separately by sex, to the age-25 body weight distribution of the observed 1920-1929 and then 1980-1989 birth cohorts. From the simulated weight distributions, they then estimated the effect on age-35 life expectancy, and ultimately concluded that if all generations represented in the current adult population were all to assume the weight distribution of the youngest birth cohort, the Hispanic life expectancy advantage would disappear for male US-born Hispanics, narrow for females, and persist for the foreign-born. However, it is important to note that this finding would not hold if the relative risk associated with obesity remained constant across racial-ethnic/nativity groups, and no other study to date has replicated a similar finding of differential mortality associated with obesity on this basis.

Research aims

Considering the uncertainty about how obesity will impact future mortality patterns in the US, I pursue two central aims in this paper:

1. Project what obesity distributions will look like for male and female US-born Hispanics, foreign-born Hispanics, and US-born whites over the next three decades starting with a nationally representative sample of adults living in the US in 2015.
2. Estimate the impact of shifting obesity distributions on future life expectancy three decades into the future to evaluate whether the Hispanic paradox in mortality is expected to persist or erode.

DATA AND METHODS

My goal is to estimate the proportionate effect of projected changes in obesity on age-specific death rates across each of the six study populations: male and female US-born whites, US-born Hispanics, and foreign-born Hispanics. To achieve this, I separately project body mass index (BMI) distributions containing both historical (i.e., retrospectively reported at age 25) and current weight and height information. I then apply multi-variate mortality risks derived from the National Health and Nutrition Examination Survey (NHANES) to the projected future obesity distributions for each of the study populations to estimate how future changes in obesity will influence future life expectancy. As with the earlier paper by Preston et al. (2014), I am not attempting to project underlying mortality rates, but instead seek to estimate the proportionate effect that projected changes in obesity will have on future age-specific mortality rates. Implicit in this approach is the assumption that the influence of obesity on future mortality remains independent from any other potential future sources of change in mortality risk that lie outside of the model estimation. I use population-level survey data from the National Health and Nutrition Examination Survey (NHANES), the National Health Interview Survey (NHIS), and the American Community Survey (ACS) to carry out various stages of the analysis, to be described in greater detail in the following sections. All analytic models were weighted and conducted in Stata/MP-2 17.0 using the `svy` command prefix (StataCorp, College Station, Texas, USA) and the projections incorporating model estimates were executed in Excel.

Projecting the effects of changes in obesity

I follow three stages of analysis to project changes in future obesity levels and estimate the associated mortality effects. First, I project current BMI distributions from 2015 to 2045 using sex, age, and racial-ethnic/nativity group-specific BMI category transition matrices derived from continuous waves of NHANES data (1999-2014). Second, I project forward the age-25 BMI distributions from 2015 to 2045 by five-year age cohorts within each of the six study populations. Third, I apply mortality risks estimated from NHANES (1988-2014) to the projected future distributions of current BMI and age-25 BMI to determine how changes in obesity will reshape future patterns in life expectancy.

Forecasting future distributions of current obesity

To forecast future obesity levels I follow a Markov modeling approach (Basu, 2010; Preston et al., 2014), that begins with an existing cohort of adults in the US and simulates their flow through mutually exclusive BMI categories over each round of projection to yield estimates of their expected future obesity distributions. This procedure is an improvement over other projection methods like linear extrapolation, which fail to account for the fact that the pool of individuals at risk of developing obesity changes as more individuals enter the category, and has produced extreme and likely implausible estimates in the past, such as that 100% of the US population will develop obesity by the year 2048 (Wang et al., 2008). At baseline (2015) individuals are distributed by their current BMI categorization and are then subjected to a set of probabilities of being found in one of the four BMI categories ten years later (2025), contingent on the category they started in at baseline. I use these same transition probabilities to reshuffle participants across BMI categories in ten-year intervals for each remaining round of the projection (2025 to 2035 and 2035 to 2045). A key analytic advantage of this approach is that it accounts for the empirical observation that future weight is affected by current weight, a pattern that has been shown to have stabilized in recent decades (Preston et al., 2014), allowing these stabilized weight transitions to be projected forward into future periods.

I derive the BMI transition probabilities from NHANES, a cross-sectional, nationally representative, population-based survey conducted by the Centers for Disease Control and Prevention (CDC) that uses a complex, multistage probability sampling strategy designed to be representative of the civilian, non-institutionalized US population (NCHS, 1996; NCHS, 2013; NCHS, 2018). I construct two key measures, current BMI and past BMI (i.e., BMI ten years prior), using data provided from the examination component of NHANES where anthropometric measurements, such as body weight and height, are taken by trained nurses. To create a measure of current BMI (kg/m^2), I use data on measured weight and height at the time of survey. To create a measure of past BMI (kg/m^2), I rely on a question administered to all NHANES participants above the age of 35, which asks “How much did you weigh 10 years ago?”. To reduce the possibility of recall bias in the measure of past BMI, I apply an individual-level correction based on the relative discrepancy between measured and self-reported weight at baseline for each participant (Flegal et al., 1995). These two measures, past BMI and current BMI, serve as the data inputs to estimate ten-year BMI category transition probabilities in an ordered logit model. I categorize both BMI measures into four classes: Normal (18.5-25.0 kg/m^2), Overweight (25.0-29.9 kg/m^2), Obese I (30.0-34.9 kg/m^2), and Obese II-III (35.0+ kg/m^2). I estimate age-, sex- and racial-ethnic/nativity group-specific transition probabilities using pooled data from continuous NHANES (1999-2014). In Figure 3-1 I show the transition matrices for males and females of each racial-ethnic/nativity group, combined and standardized by age for the purposes of summary and comparison.

To project BMI distributions forward from 2015, I begin with initial population counts for each racial-ethnic/nativity group stratified by sex, which I derive from the 2015 American

Community Survey (ACS) (Ruggles et al., 2021). I then array individuals in each group according to proportional BMI distributions by five-year age category (25-29 through 80-84) that are estimated within NHANES (2013–2016). For each round of projection, I survive members of the population forward ten years using ten-year survival ratios taken from the 2015 US life tables from the National Center for Health Statistics (NCHS) (Arias, 2018). For example, the ratio of $l_{37.5}/l_{27.5}$ represents the probability of 25-29 year-olds in 2015 surviving to ages 35-39 in 2025.

However, since the NCHS does not provide BMI-specific life tables, and also, does not publish separate life tables for US-born and foreign-born Hispanics, I had to first generate BMI- and racial-ethnic/nativity-group-specific life tables in order to obtain the appropriate age-specific survival probabilities for each racial-ethnic/nativity group stratified by BMI category and sex. To do this, I derived BMI category-specific mortality risks from NHANES (1988–2014 with mortality follow-up through 2015) and the mortality risk ratio for US-born vs. foreign-born Hispanics from the National Health Interview Study (NHIS 1989-2014). Given the lack of consensus around heightened mortality risk from overweight status, particularly in mid-and-later life (Flegal et al., 2013), I collapse the Normal/Overweight categories in the survival model to estimate relative mortality risks of the two categories of obesity (class I and class II/III) relative to non-obese status. The NHANES sample used in the survival model is described in Table 3-1. Using the relative mortality risks derived from each of these data sources I differentiated the four original NCHS life tables for male/female non-Hispanic whites and male/female Hispanics into eighteen separate life tables, fully-differentiated by nativity for Hispanics and into the collapsed BMI categories (Normal/Overweight, Obese I, and Obese II).

Equation Set 1 demonstrates how I differentiated the NCHS life tables based on three-categories of BMI, while still ensuring the combined average across all weight categories matched published NCHS estimates. For example, to calculate the new q_x values for those in the Normal/Overweight category (q_0) for each five-year age category ($_a$) I divide the original race-ethnicity/sex-specific q_x value ($\bar{q}$) provided by NCHS by the proportion (p) in each of the three BMI risk categories (denoted as 0 through 2) multiplied by the relative risk of that weight category compared to the baseline. I use this new set of BMI-specific q_x's as the basis for the new fully stratified life tables using standard demographic methods. I also employed this same approach, adapting the set of equations below, for use with two risk categories when differentiating the Hispanic life tables by nativity status in the preceding step.

(Equation Set 1)

(1) $\bar{q}_a = q_{0_a} \cdot p_{0_a} + q_{1_a} \cdot p_{1_a} + q_{2_a} \cdot p_{2_a}$

Note. $RR_{1_a} = {q_{1_a}}/{q_{0_a}}$, $RR_{2_a} = {q_{2_a}}/{q_{0_a}}$, ${RR_{2_a}}/{RR_{1_a}} = {q_{2_a}}/{q_{1_a}}$

(2) ${\bar{q}_a}/{q_{0_a}} = p_{0_a} + RR_{1_a} \cdot p_{1_a} + RR_{2_a} \cdot p_{2_a}$

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$$q_{0_a} = \frac{\bar{q}_a}{p_{0_a} + RR_{1_a} \cdot p_{1_a} + RR_{2_a} \cdot p_{2_a}}$$

(3) ${\bar{q}_a}/{q_{1_a}} = {p_{0_a}}/{RR_{1_a}} + p_{1_a} + \left({RR_{2_a}}/{RR_{1_a}} \cdot p_{2_a}\right)$

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$$q_{1_a} = \frac{\bar{q}_a}{{p_{0_a}}/{RR_{1_a}} + p_{1_a} + \left({RR_{2_a}}/{RR_{1_a}} \cdot p_{2_a}\right)}$$

$$(4) \quad \bar{q}_a / q_{2_a} = {p_0}_a / {RR_2}_a + \left({RR_1}_a / {RR_2}_a \cdot {p_1}_a \right) + {p_2}_a$$

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$$q_{2_a} = \frac{\bar{q}_a}{{p_0}_a / {RR_2}_a + \left({RR_1}_a / {RR_2}_a \cdot {p_1}_a \right) + {p_2}_a}$$

In the second step of the projection, I redistribute surviving members of the population into new BMI categories according to sex-, age-, racial-ethnic/nativity group-, and BMI-specific transition probabilities. The new BMI distributions of the survivors, along with the entry of new cohorts of 25-29 and 30-34 year-olds for each round of projection, provide the new population counts and projected BMI levels for each future period. I determine the size of the entering 25-29 and 30-34-year-old cohorts using published population projections from the US Census Bureau (2017) and extrapolate historical trends to predict their future BMI distributions.[1]

Forecasting future distributions of age-25 obesity

In parallel with the projections of current BMI, I also project age-25 BMI levels for all cohorts that will be aged 25–84 within the projection timeframe. I, again, begin with initial population counts in 2015 for each racial-ethnic/nativity group stratified by sex taken from the ACS, and then array them according to age-25 BMI distributions from NHANES (2013–2016). I calculate age-25 BMI by combining self-reported weight at age 25 (corrected for self-report bias)

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[1] I use measured data on height and weight from the continuous NHANES waves (1999–2014) to estimate a historical series as the basis to predict BMI distributions in future periods. I organize the data by three-year birth cohorts for all participants aged 25 at the time of survey and determine the proportion in each BMI category for each of the three-year cohorts. Next, I regress the proportion in each BMI category on the logarithm of time (years since 1970), indicators for sex and racial-ethnic/nativity group, and interactions between time and racial-ethnic/nativity group and between sex and racial-ethnic/nativity group. Using these model parameters, I predict the future proportions in each category of BMI for each study population in 2025, 2035, and 2045.

with one of two height measures: for individuals younger than 50 at the time of survey I use the exam-based height measure, and for individuals aged 50 or older I use self-reported height at age 25. Since an individual's BMI at age-25 becomes a fixed characteristic once it is first observed, there is no reshuffling step in this round of projections. Thus, the next step is to survive forward the initial distributions in five-year intervals using racial-ethnic/nativity group, sex-, age-, and age-25 BMI specific life tables that were differentiated using the same approach described above for current BMI. As with the projections of current BMI, I use Census projections and an extrapolation of the historical trend within NHANES to fill in the future population counts and BMI distributions for the new cohorts of 25-29 year-olds that join the projections in 2020, 2025, 2030, 2035, 2040, and 2045.

Estimating mortality risk by BMI category: complementary log-log regression

Data for the mortality analysis to establish the relative risks of current and age-25 BMI come from pooled waves of NHANES III (1988–1994) and continuous NHANES (1999–2014) with mortality follow-up provided by linked National Death Index files through 2015. The key dependent variable is mortality and the two main independent variables of interest are current BMI and age-25 BMI. In effort to reduce bias in estimates of the mortality effects of obesity from reverse causation, I eliminate the first three years of exposure and also exclude individuals with emphysema or a smoking-related cancer[2] at baseline. I also adjust the survey weights in NHANES for the mortality analysis to account for potential bias introduced by differences in linkage ineligibility or non-matches across the six study populations (NCHS, 2012). Finally, I

[2] The category of smoking-related cancers includes cancers of the lung, larynx, mouth/tongue/lip, esophagus, bladder, kidney, and pancreas (Pirie et al., 2013).

also exclude anyone from the analytic sample who was pregnant at the time of examination or who had current, past, or age-25 BMI readings that fell outside risk estimable categories (i.e., were classified as underweight, BMI < 18.5 kg/m^2). The discrete hazards survival model was estimated using complementary log-log regression on person-year data for a sample of 20,554 subjects, representing 137,486.8 person-years at risk and 3,277 deaths. Full descriptive details on the analytic sample are summarized in Table 3-1 and model estimates are provided in Table B-1 of the appendix.

Validation of transition matrices and projection methodology

To help validate the BMI transition matrices and justify their use to predict future trajectories, I demonstrate their reliability in predicting changes in BMI that have already occurred. To do this, I follow the exact methodology used for the main set of projections (described above), but instead begin with initial BMI distributions in 2005 that I survive forward to 2015. I then compare the predicted values in each BMI category based on my projections to the actual values observed in NHANES for the 2015 time period to assess the fit of the modeling approach. The results, available Tables B-2 and B-3 of the appendix, demonstrate that predicted BMI levels using the outlined projection approach fell within the 95% confidence intervals of the actual observed values roughly 88% of the time with a mean RMSE of 0.05. I interpret these measures as signs of good concordance between the predictions and observed values, thus validating the projection approach that relies on BMI category transition probabilities derived from current and historical weight data from NHANES.

Uncertainty analysis

I account for uncertainty in the estimations of the effects of obesity on life expectancy from three main sources: the estimation of BMI transition probabilities, relative risks to differentiate BMI-specific and nativity-specific life tables, and parameters of the survival model relating current and age-25 BMI to mortality. The transition probabilities were estimated using an ordered logit model, and relative risks to differentiate life tables and to relate BMI to mortality were estimated using a discrete hazards model. I use the mean parameter estimates and standard errors from these models to simulate a set of 500 possible coefficients under a random normal distribution for each model. Using these simulated coefficients, I generate 500 sets of transition matrices and life tables, and then use these to generate 500 predictions of current and age-25 obesity in 2025, 2035, and 2045. The coefficients of the survival model are then applied to each obesity projection to predict a range of life expectancy effects incorporating uncertainty from each prior step of analysis. To construct 95% confidence intervals (CI) I extract the 2.5 and 97.5 percentile values.

RESULTS

Descriptive statistics

Table 3-1 summarizes the weighted characteristics and outcomes of each racial-ethnic/nativity group separately for males and females. Foreign-born Hispanic males are the youngest group in the sample with a mean age of 49.4 years, and for both sexes US-born and foreign-born Hispanics are significantly younger than their US-born white counterparts, with an average gap of roughly 4 years between whites and Hispanics. The mean year of interview fell between 2002-2004 for all groups, with the earliest mean year of interview recorded for male and female US-born whites. US-born whites of both sexes also received the most education, with the highest proportions attending at least some college and the lowest proportions completing their education before high school. Male and female foreign-born Hispanics had the lowest levels of education, with the highest proportions completing their education before graduating high school and the lowest proportions attending college. US-born Hispanics had educational achievement levels falling between the two other racial-ethnic/nativity groups. Foreign-born Hispanics of both sexes had the least amount of smoking behavior and history across all groups, with female foreign-born Hispanics, in particular, representing a clear outlier amongst all groups with 72.7% reporting they had never smoked. The smoking profiles of US-born whites and US-born Hispanics are not significantly distinguishable. Among males, US-born whites and foreign-born Hispanics have similar current BMI profiles, while US-born Hispanics generally have higher proportions in the obese categories. Among females, US-born whites generally have a lower BMI profile than US-born Hispanics and foreign-born Hispanics. With BMI measured at age 25, both male and female foreign-born Hispanics have the greatest proportions in the highest class of obesity (II/III). With past BMI reported ten years prior to interview, male foreign-born Hispanics display a clear Hispanic health advantage, with the highest proportion in the normal weight category and lowest proportions in both classes of obesity (I and II/III). Yet it is notable that this advantage has begun to erode in the decade leading up to the current measurement period, which is consistent with prior research on the erosion of the initial Hispanic health advantage in obesity and metabolic syndrome with increasing time spent in the US (Chapter 2/Carabello & Wolfson, 2021). Foreign-born females did not exhibit the same advantage over US-born whites on this historical measure of BMI ten years prior. Among females, there is a clear Hispanic paradox in mortality among both foreign-born and US-born Hispanics as compared to US-born whites, while this mortality advantage is only maintained for the foreign-born, and not the US-born, among males.

BMI transitions

Figure 3-1 summarizes the sets of age-standardized 10-year BMI transition matrices by sex and racial-ethnic/nativity group. The rows indicate the starting BMI category, while the columns indicate the final BMI category. For example, the light blue tile in the upper left-hand corner indicates that the probability of a US-born white male remaining in the normal BMI category if they were to start there ten years prior is 0.62. Looking down the diagonal of each square from left-to-right indicates the probabilities of remaining in the BMI category one started in. Looking at the tiles in the upper-right of each square, therefore, gives a good indication of the intensity of transitioning to higher BMI categories, which is visually depicted by lighter shades of blue. While the differences across groups are modest, summing the probabilities in these upper-right squares confirms that transitions toward higher BMI categories were slightly more intense for females compared to males, and for both US-born and foreign-born Hispanics versus US-born whites.

Observed and projected obesity distributions

The graphs in Figure 3-2 summarize both observed and projected trends in current BMI. Among males at the initial period in 2015, foreign-born Hispanics have the lowest levels of obesity with a class I prevalence of 0.26 and a class II/III prevalence of 0.12. By 2045 they have a slightly higher proportion in the two obesity classes as compared to US-born whites yet maintain a lower obesity distribution overall due to a much smaller share in the class II/III obesity category with a prevalence of 0.16 for foreign-born Hispanics in comparison to 0.23 for US-born whites. Males US-born Hispanics maintain the highest levels of obesity across the observed and projected periods, yet the gap relative to US-born whites narrows over time. Among females, beginning in 2015, US-born whites have the lowest obesity prevalence overall with 0.21 in class I and 0.22 in class II/III, yet foreign-born Hispanics have a much lower prevalence of class II/III obesity of 0.19 at baseline. By 2045, female US-born whites have a clearer advantage over female foreign-born Hispanics, as the rise of obesity among foreign-born Hispanics outpaces whites in both categories. Female US-born Hispanics maintain the highest levels of obesity across the observed and projected periods, yet the gap relative to US-born whites does not widen across the years of projection.

Looking at the overall trends in obesity across racial-ethnic/nativity categories for both males and females, there are two main patterns to note. First, although current BMI is higher for US-born Hispanics at baseline, projected increases follow similar trends as those for US-born whites, with the exception of female US-born Hispanics, who are projected to experience the steepest rise in class II/III out of all the groups. Second, both male and female foreign-born Hispanics started with the lowest levels of class II/III obesity and had the shallowest projected growth in this higher-risk category.

Effect of changes in obesity distribution on life expectancy

The series of graphs shown in Figure 3-3 illustrates the effect of projected trends in BMI on age-specific mortality rates. One takeaway from this figure is that the proportionate increases in mortality risk attributable to obesity were trending upwards, and generally peaked, at younger ages for US-born whites and foreign-born Hispanics as compared to US-born Hispanics, likely reflecting both steeper increases in current BMI at these younger ages along with higher BMI measured at age 25 among the younger age cohorts, which would have a greater combined impact on their age-40 life expectancy than had those peaks occurred at later ages. In contrast, for male and female US-born Hispanics, the peak in the projected effects on mortality occur at older ages, roughly between 60-75 years-old, which would be expected to have a less significant impact on future life expectancy at age-40 than had these peaks occurred at younger ages.

Table 3-2 summarizes the expected impact that future trends in obesity will have on age-40 life expectancy by racial-ethnic/nativity group and sex. By 2045, our projections estimate that shifts towards higher body weight distributions will have sizable effects for all population groups, ranging from losing 0.74 years of expected life after age 40 for male foreign-born Hispanics to losing 1.48 years for female US-born Hispanics. Overall, the expected impacts within racial-ethnic/nativity categories are lower for males than females. Across racial-ethnic/nativity groups, the smallest expected impacts are for foreign-born Hispanics and the largest are for US-born Hispanics, followed closely by US-born whites. However, it is important to note that based on the uncertainty analysis, none of the estimated effects on age-40 life expectancy can be considered statistically significant; a limitation I will discuss further.

DISCUSSION

In this paper I first aimed to project what obesity distributions will look like for male and female US-born Hispanics, foreign-born Hispanics, and US-born whites over the next three decades, beginning with a cohort of adults living in the US in 2015. I found that despite having the highest distributions of obesity at baseline, projected future trends in obesity for US-born Hispanics are expected to follow a similar pattern to whites overall. This finding is consistent with the recent narrowing in the once stark obesity prevalence gap between US-born whites and

Hispanics documented between two prior NHANES-based studies (Flegal et al., 2016; Hales et al., 2020). Projections of future obesity distributions also reveal a typical pattern of immigrant health advantage among foreign-born Hispanics, as they started with the lowest levels of class II/III obesity in 2015 and generally had the shallowest projected growth in this higher-risk category in the future projections through 2045, particularly for males.

My second aim was to estimate the impact of shifting obesity distributions on future life expectancy three decades into the future to evaluate whether the Hispanic paradox in mortality is expected to persist or erode. Overall, I find that the expected impact of changes in obesity on future life expectancy are generally lower for males than females, and across racial-ethnic/nativity groups, are expected to be smallest for foreign-born Hispanics and the largest for US-born Hispanics, followed closely by US-born whites. According to the main sets of estimates, I would expect changes in obesity to narrow the mortality gap between US-born Hispanics and US-born whites, yet not to a sufficient extent to erode Hispanics' advantage entirely. Meanwhile, the mortality gap favoring foreign-born Hispanics would be expected to widen slightly, which may cause the net effect on the overall mortality gap favoring all Hispanics over US-born whites to remain largely unaffected by future obesity trends. Looking beyond the comparisons across racial-ethnic/nativity groups, it is also useful to evaluate these estimates within the context of general expectations about future life expectancy. According to life expectancy projections published by the Social Security Administration, male life expectancy at age-40 in the US is expected to increase by 2.40 years between 2020 and 2050 and females are expected to gain 2.02 years in life expectancy over the same period (Bell and Miller, 2005). While the SSA's estimates are not differentiated by racial-ethnic/nativity category, if assumed to apply to all groups, the projected effects from my estimates indicate a penalty imposed by obesity against future life expectancy gains in the range of 31-50% for males and 44-73% for females. This is a clear indication of obesity's potential to significantly influence US mortality for years to come.

As I note in the paper's background, given the diminishing role of smoking as a key explanation of mortality differentials between whites and Hispanics, at least one of two things would need to be true for obesity to erode the Hispanic mortality advantage over the next few decades. One of these factors would be if future trends in obesity prevalence for Hispanics were to continue to outpace those of whites, which was not indicated by the projections of future obesity distributions that I have estimated in this paper. The second factor, which would then become necessary for obesity to erode the Hispanic mortality advantage, would be if Hispanics faced an elevated mortality burden from obesity as compared to whites. As indicated by the parameters from the discrete hazards model summarized in Table B-1 of the appendix, I found no evidence of a significant difference in the mortality risk imposed by obesity across the racial-ethnic/nativity groups in this sample. On this basis, I conclude that obesity is expected to have a large and comparable effect on US mortality for all groups, and thus is unlikely to significantly reshape the existing Hispanic advantage in life expectancy within the foreseeable future.

However, an important caveat in interpreting these results is that none of the estimates of proportionate change in age-40 life expectancy were found to be statistically significant according to the uncertainty analysis, and thus the conclusions should be interpreted cautiously. To that end, I discuss some of the limitations with the current analytic approach below and then compare my results to other published estimates to provide greater context to aid in their interpretation.

The main source of limitation in the current approach is the inflated standard errors in estimates due to small sample size issues, which magnify the uncertainty that is introduced and carried through each round of the 500 simulated projections that were run to construct 95% confidence intervals around reported estimates. This is a unique limitation to this study relative to similar projects with shared methodologies or aims. It was essential to the nature of my research questions to stratify the sample into smaller groups for analysis as compared to a similar study using the same data source and a similar sample size without first stratifying by racial-ethnic/nativity group (Preston et al., 2014) or another study using a similar stratification strategy with an alternate data source lacking directly measured height/weight data (i.e., the NHIS), but boasting a sample size over 35-times the size of that available in NHANES (Van Hook et al., 2020). That said, comparing the main estimates in the current study to the results published in these prior studies is perhaps the best way to contextualize the plausibility of my estimates despite the difference in confidence levels.

While the earlier paper by Preston et al. (2014) did not report separate estimates by racial-ethnic/nativity group, I can reasonably compare their projected changes in life expectancy at age-40 by 2040 to my own estimates for US-born whites in 2045 with the knowledge that non-Hispanic whites were the predominant racial-ethnic group in their sample and that racial-ethnic category was controlled for in their discrete hazards model predicting the mortality risk associated with obesity. By 2040, Preston et al. (2014) predict a change in age-40 life expectancy due to obesity of –0.73 (95% CI –1.04, –0.47) and –0.82 years for females (95% CI –1.17, –0.47). By 2045, I predict a change in age-40 life expectancy due to obesity of –1.05 for male US-born whites and –1.29 for female US-born whites. While my estimates are higher in magnitude than Preston et al.'s (2014), given the differences in racial-ethnic composition of our samples and the fact that my projections are carried out five additional years into the future, the two sets of estimates appear largely comparable.

The comparison of my estimates to those published by Van Hook et al. (2020) is less straightforward given far greater differences in methodology, focus, and data approaches between our two studies. To recap Van Hook et al.'s (2020) study, first mentioned in the background section of this paper, it represents the only existing publication to empirically explore how generational shifts in obesity might impact the future of the Hispanic paradox. The authors used a counterfactual approach assigning everyone to the age-25 body weight distribution of the 1920-1929 and then 1980-1989 birth cohorts, estimate the change this would impose on age-35 life expectancy, and ultimately conclude that if the population were to assume the weight distribution of the younger birth cohort the Hispanic life expectancy advantage would disappear for US-born Hispanic males, narrow for females, and persist for the foreign-born. While it is not a natural population process to assume that any population of adults aged 25-84 representing six different ten-year birth cohorts would ever uniformly assume the weight distribution of any single birth cohort in the same period, their simulation is still an informative exercise to assess future scenarios, and for purposes of comparison I can roughly consider it a projection occurring over a 60-year timeline. Therefore, for my estimates to be considered reasonably comparable, I would expect the magnitude of Van Hook et al.'s (2020) to be no more than double mine. The simulated change in life expectancy at age-25 was –1.4 years for male foreign-born Hispanics (1.9 times my estimate of –0.74), –3.3 for male US-born Hispanics (2.7 times my estimate of –1.20), –1.5 for male US-born whites (1.4 times my estimate of –1.05), –1.8 for female foreign-born Hispanics (2.04 times my estimate of –0.88), –3.1 for female US-born Hispanics (2.1 times my estimate of –1.48), and –2.2 for female US-born whites (1.7 times my estimate of –1.29). Despite the difficulties in making a direct comparison between these two sets of results, it is notable that the only estimate that was significantly more than double my own was that for male US-born Hispanics, the one group they predicted would lose their mortality advantage altogether if future generations were to assume the heightened weight distribution of the cohort of young adults alive today.

CONCLUSION

Based on the current paper and the existing evidence published to date, I tentatively conclude that the continuation of observed trends of increasing obesity will not meaningfully reshape US mortality patterns by race-ethnicity/nativity, as all groups are projected to experience similar and increasingly more gradual rises in obesity over the coming decades. The only scenario under which we might expect US-born Hispanics to lose their mortality advantage due to the influence of obesity would be if they were to face a higher risk of dying at various BMI categories as compared to US-born whites. Exploring this scenario as more datasets with larger Hispanic samples become available will therefore be an important research pursuit in coming years. That said, whether the Hispanic paradox is expected to persist or erode, it is important to maintain sight of the fact that obesity is expected to continue to exert a significant influence on US mortality across all racial-ethnic groups, and thus warrants continued monitoring and analysis taking advantage of all available data sources and new and innovative modeling approaches to help overcome current data limitations.

Table 3-1. Weighted descriptive characteristics and outcomes by sex and race-ethnicity/nativity group in the National Health and Nutrition Examination Survey (NHANES, 1988-2014 with mortality follow-up through 2015)

	Male			Female		
Characteristics	US-born whites	US-born Hispanics	Foreign-born Hispanics	US-born whites	US-born Hispanics	Foreign-born Hispanics
Age at interview, [mean (SE)]	54.1[†‡]	51.2[*‡]	49.4[*†]	55.6[†‡]	51.4[*]	51.0[*]
	(.192)	(.555)	(.383)	(.251)	(.447)	(.441)
Year of interview, [mean (SE)]	2002.6[‡]	2003.2	2004.1[*]	2002.4[‡]	2003.4	2003.7[*]
	(.202)	(.407)	(.378)	(.239)	(.395)	(.410)
Education [%]						
Less than high school	11.5[†‡]	29.0[*‡]	58.8[*†]	12.2[†‡]	29.0[*‡]	59.8[*†]
High school or GED	25.4[‡]	25.5[‡]	14.5[*†]	26.0[‡]	27.0[‡]	14.7[*†]
Some college or college graduate	63.1[†‡]	45.6[*‡]	26.6[*†]	61.8[†‡]	44.0[*‡]	25.5[*†]
Smoking status [%]						
Never smoker	39.7[‡]	38.1[‡]	44.1[*†]	52.8[‡]	55.3[‡]	72.7[*†]
Former smoker	36.3[‡]	32.3	32.5[*]	26.3[†‡]	21.6[*‡]	14.0[*†]
Current smoker	24.0[†]	29.6[*‡]	23.4[†]	20.9[‡]	23.1[‡]	13.3[*†]
Current BMI [%]						
Normal (18.5-24.9 kg/m^2)	22.0[†‡]	16.6[*]	18.4[*]	32.2[†‡]	20.2[*]	19.3[*]
Overweight (25.0-29.9 kg/m^2)	43.9[‡]	40.3[‡]	50.0[*†]	30.6[‡]	31.5	36.3[*]
Obese I (30.0-34.9 kg/m^2)	23.0[†]	28.5[*‡]	23.8[†]	19.8[‡]	22.5[‡]	28.4[*†]
Obese II-III (35.0+ kg/m^2)	11.1[‡]	14.6[‡]	7.8[*†]	17.3[†]	25.8[*‡]	16.0[†]
Age-25 BMI [%]						
Normal (18.5-24.9 kg/m^2)	57.1	53.4	57.9	75.8[†‡]	64.3[*‡]	58.1[*†]
Overweight (25.0-29.9 kg/m^2)	32.3[‡]	31.6[‡]	24.9[*†]	13.6[†‡]	17.9[*]	18.1[*]
Obese I (30.0-34.9 kg/m^2)	6.3[‡]	8.8[‡]	4.1[*†]	4.2	5.5	4.2
Obese II-III (35.0+ kg/m^2)	4.3[†‡]	6.3[*‡]	13.1[*†]	6.4[†‡]	12.3[*‡]	19.7[*†]
Past BMI, 10 years prior to interview [%]						
Normal (18.5-24.9 kg/m^2)	30.3[‡]	27.4[‡]	36.0[*†]	46.1[†‡]	39.4[*]	40.1[*]
Overweight (25.0-29.9 kg/m^2)	44.9	43.9	46.8	30.5[‡]	31.8	35.3[*]
Obese I (30.0-34.9 kg/m^2)	17.3[‡]	19.7[‡]	13.7[*†]	13.6	15.5	16.1
Obese II-III (35.0+ kg/m^2)	7.5[‡]	9.0[‡]	3.5[*†]	9.8[†]	13.3[*‡]	8.5[†]
Died during follow-up [%]	15.8[‡]	13.5[‡]	7.8[*†]	13.9[†‡]	8.9[*]	8.9[*]
Unweighted *N*	6,613	1,439	2,189	6,575	1,560	2,178
Unweighted number of deaths	1,251	265	268	1,073	199	221

Notes. Weighted descriptive statistics. Symbols indicate a statistically significant difference at the $\alpha = 0.05$ level in proportions/means between the respective group in each column and US-born whites (*), US-born Hispanics (†), and foreign-born Hispanics (‡); comparisons made within sex categories.
Data source. Data are derived from pooled waves of NHANES III (1988-1994) and continuous NHANES 1999-2000 through 2013-2014 with mortality follow-up provided by the National Death Index through December 2015.

Table 3-2. Projected proportionate changes in age-40 life expectancy (e40) in years

Year	Male			Female		
	US-born whites	US-born Hispanics	Foreign-born Hispanics	US-born whites	US-born Hispanics	Foreign-born Hispanics
2025	–0.56 (–1.49, 0.54)	–0.84 (–2.54, 0.91)	–0.36 (–1.74, 0.84)	–0.65 (–2.08, 0.91)	–0.85 (–2.42, 0.89)	–0.42 (–1.97, 1.51)
2035	–0.85 (–2.10, 0.66)	–1.13 (–3.26, 1.11)	–0.64 (–2.33, 1.18)	–1.07 (–2.95, 1.24)	–0.86 (–3.30, 2.59)	–0.69 (–2.64, 1.81)
2045	–1.05 (–2.51, 0.74)	-1.20 (–3.39, 1.08)	-0.74 (–2.47, 1.09)	–1.29 (–3.34, 1.33)	–1.48 (–3.82, 1.57)	–0.88 (–3.00, 1.81)

Figure 3-1. Age-standardized 10-year BMI transition matrices from the National Health and Nutrition Examination Survey (NHANES 1999-2014)

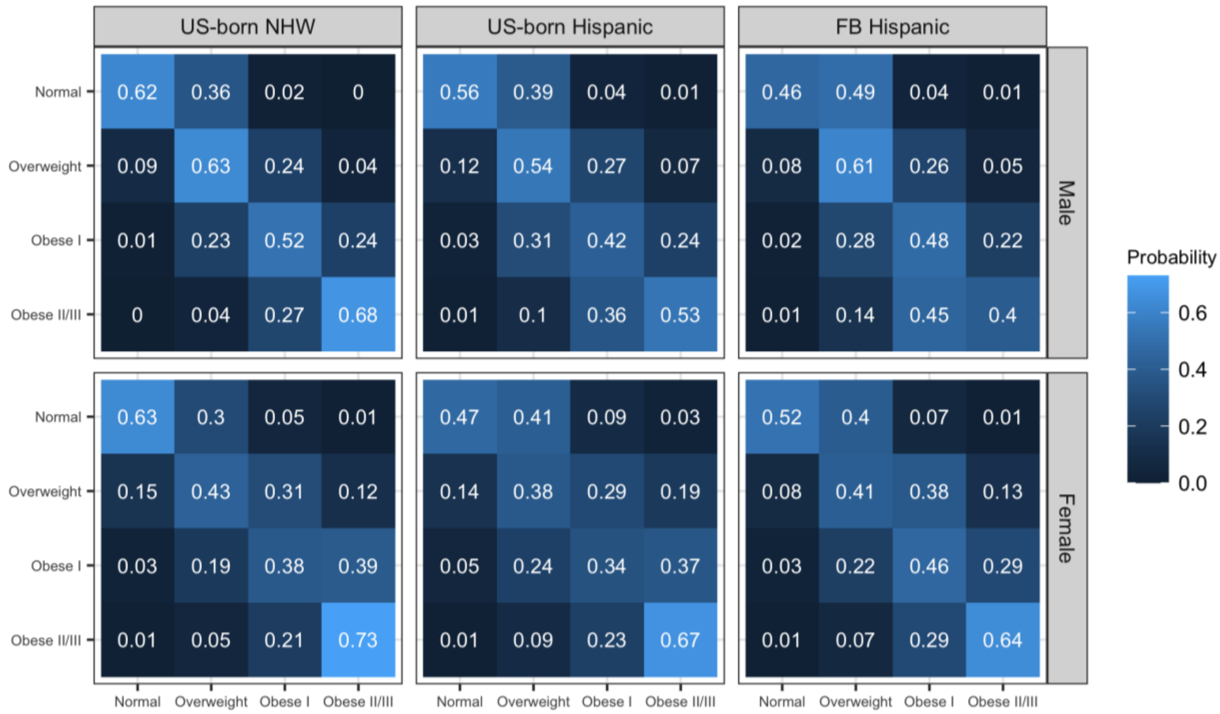
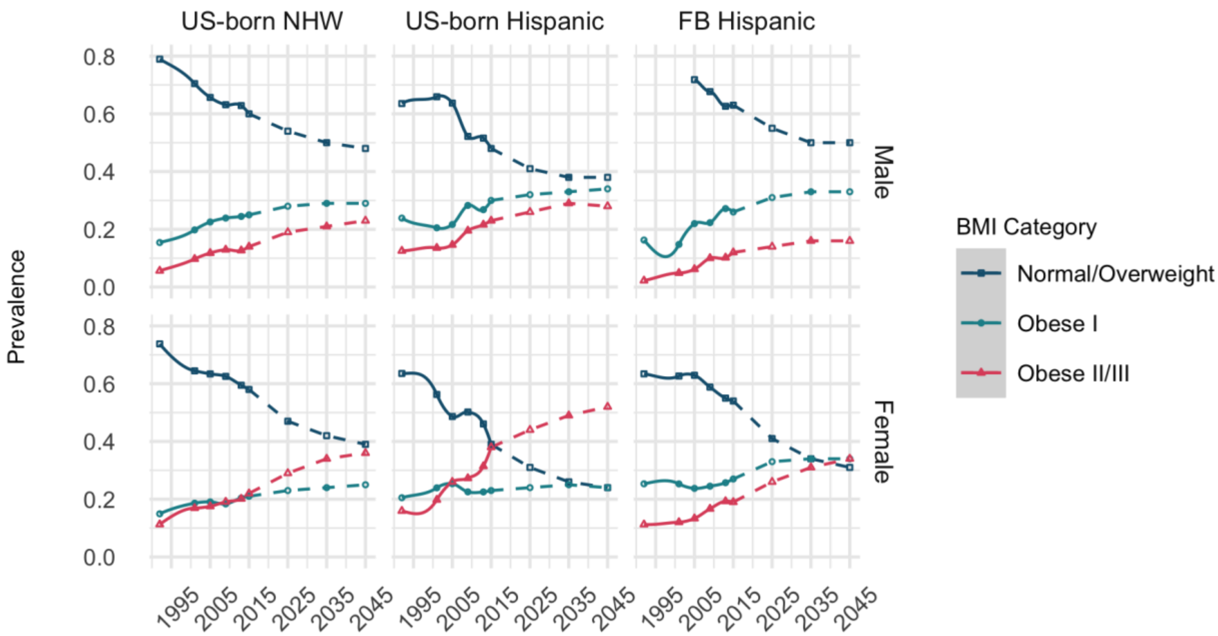
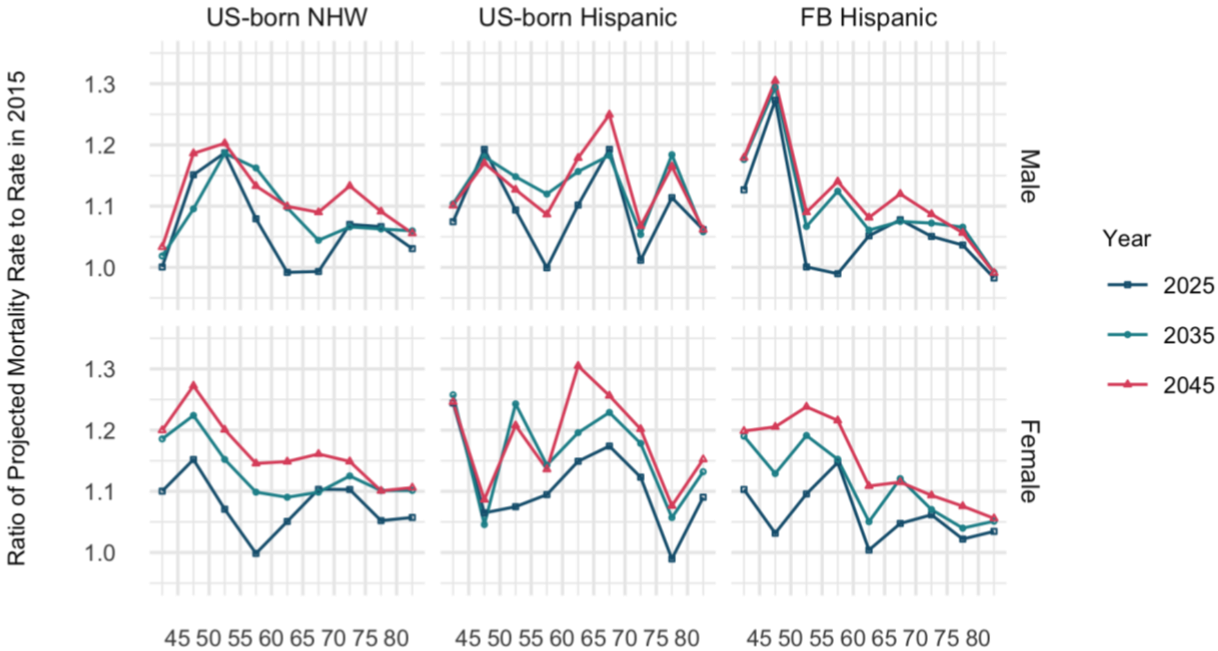


Figure 3-2. Actual and projected trends in body mass index (BMI)



Notes. Solid lines indicate observed trends while dotted lines indicate projections. Data for the historical series are calculated using NHANES III (1988-1994) and continuous NHANES 1999–2002, 2003–2006, 2007–2010, and 2011–2014.

Figure 3-3. Effect of projected trends in BMI on age-specific mortality rates



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Chapter 4 – Metabolic Health and Mortality Among Older Hispanics in the US and Mexico: Focusing on the Role of Diabetes

INTRODUCTION

The United States (US) population is both rapidly diversifying and aging, and Hispanic Americans represent a critical group at the center of both demographic processes. Hispanics are the largest and one of the fastest-growing minority groups in the US, representing 17.8% of the total population, and accounting for half of US population growth in this century (Flores, 2017; U.S. Census Bureau, 2017). More than a third of US Hispanics are foreign-born, with Mexico representing the most common origin country (Flores, 2017). The share of the US population over the age of 65 is also increasing, and Hispanics represent the fastest growing segment of this aging population (Vincent, 2010). Given Hispanics' prominent role in the twin population dynamics of diversification and aging, anticipating potential vulnerabilities to the health and longevity of older Hispanics marks a clear priority area for population health and policy planning.

Much of the research on the health of Hispanic populations in the US has been dominated by interest in the Hispanic paradox in health and mortality—that is, the finding that Hispanics generally live longer and experience better health than non-Hispanic whites despite their lower socioeconomic status (Markides & Coreil, 1986; Markides & Eschbach, 2005). The evidence for this finding has been particularly strong for the lower mortality and greater longevity experienced by foreign-born Mexican Americans relative to non-Hispanic whites and Blacks across the lifespan (Lariscy et al., 2015). Studies have largely attributed this persistent pattern to selective migration, with in-migrants selected positively and out-migrants selected negatively on health and related attributes, as well as to differences in key health behaviors favoring first- and later-generation Hispanic immigrants, particularly smoking (Blue & Fenelon, 2011; Fenelon, 2013; Markides & Eschbach, 2005). However, evidence suggests that Hispanics' lower rates of mortality, health complications, and disability may not translate into a continued advantage that persists into older ages, particularly among US-born Hispanics over the age of 65 (Garcia et al., 2017; Lariscy et al., 2015; Sheftel, 2017). Advancing a more complete understanding of current health and mortality patterns among older Hispanics by nativity status and country of origin will thus be critical for anticipating how best to support the health of this rapidly growing and aging demographic group.

Diabetes, obesity, and a constellation of related conditions that compose metabolic syndrome (MetS) have emerged as some of the most immediate and critical threats to the health, quality of life, and longevity of older Hispanics (Garcia et al., 2017). Among the US-born population, the rise in obesity between the mid-1990's and mid-2010's, was steeper among Hispanics aged 55-59 than among non-Hispanic whites in the same age range, with the prevalence rising from 5% to 20% and 8% to 18% among male and female Hispanics respectively, and 5% to 13% and 7% to 17% among male and female non-Hispanics (Hudomiet et al., 2022). This same cohort has also experienced similar patterns in related metabolic conditions and is now entering into older adulthood with the highest rates of diabetes of any racial-ethnic group in the US population (Aguayo-Mazzucato et al., 2019; Alegre-Díaz et al., 2016; Cheng et al., 2019). Heightened metabolic risks heading into older adulthood are also likely to negatively impact the long-term health and longevity of foreign-born Hispanics.

Although younger Mexican immigrants have been found to exhibit a metabolic health advantage at the time of migration, after a decade or more in the US, this initial advantage is lost and they typically enter mid- and later-life with higher rates of metabolic health complications than US-born whites (Chapter2/Carabello & Wolfson, 2021). It is also known that diabetes is currently the top cause of death in Mexico (Alegre-Díaz et al., 2016), yet diabetes-specific mortality patterns remain understudied among the US Hispanic and Mexican-origin populations despite the rising prevalence over the past two decades (Aguayo-Mazzucato et al., 2019). Given the strength of the global evidence linking increased metabolic health burden and mortality risk (Alberti et al., 2009; Eckel et al., 2010), this is a critical moment to gain a more detailed portrait of the current patterning of metabolic health among aging first- and later-generation Mexican immigrants to the US, relative to both non-migrants in their country of origin and the US population, to better anticipate and alleviate potential mortality risks and long-term care needs over the coming decades.

As such, in this study, I pursue the following research aims:

1. Among adults over the age of 50, determine the current distribution of metabolic health conditions across Mexican origin populations—both those living in Mexico and those who have migrated to the US—as compared to US-born whites and US-born Mexican Americans.
2. Explore whether differences in the distribution of metabolic health conditions translate into differences in the associated population attributable mortality risks.
3. Assess how controlling metabolic conditions with the highest mortality risk would compare to the effect of eliminating a known high-risk behavioral exposure, such as smoking.

METHODS

Data and sample

To answer these questions, I used two harmonized population-based data sources of late middle-aged and older adults in the United States and Mexico. The primary dataset comes from the US Health and Retirement Study (HRS), a nationally representative longitudinal study of older adults in the US over the age of 50 collecting data on their social, economic, physical, and psychological well-being. The HRS is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan. A fuller description of the HRS survey and sample cohorts can be found elsewhere (Sonnega et al., 2014). To construct my analytic sample, I used the RAND HRS harmonized files (RAND HRS, 2021), which includes information on the six entry cohorts interviewed between 1992 and 2014 with mortality information available in the tracker files through June 1, 2019. I appended these core data files with the HRS biomarker files containing physical health data taken through anthropometric measures and blood samples beginning with a random half of the study sample in 2006 and the remaining half in 2008, along with the subsequent examinations taken on the full sample every two years thereafter (i.e., 2010, 2012, and 2014). I excluded respondents not in the study populations of interest, who did not participate in one or more years of the biomarker examinations, or were not age 50 or older between 2006 and 2014, leaving an eligible sample of 13,479 individuals. Further exclusions were made for individuals that did not have complete MetS information in at least one wave (n = 1,213), creating a final analytic sample of 12,266 individuals (91.0% of eligible sample). The HRS sample represents an unbalanced panel with each respondent contributing between 1 and 6 observations, with an average of 4.08 observations per subject. I transformed the original data structure into long form person-year data files resulting in a final HRS sample of 12,266 respondents: 10,977 US-born non-Hispanic whites representing 89,629.9 person years at risk and 1,982 deaths, 538 US-born Mexican Americans representing 4,021.8 person years at risk and 58 deaths, and 711 foreign-born Mexicans in the US representing 4,739.7 person years at risk and 36 deaths. While this analytic sample may appear to underrepresent US-born Mexican Americans and foreign-born Mexicans relative to US-born non-Hispanic whites, the two Mexican-origin groups combine to represent 10.2% of the final analytic sample, which falls in line with expectations based on the fact that all Hispanics combined comprise a share of 11.2% in an overall HRS sample restricted to only Hispanics and non-Hispanic whites (Crimmins et al., 2004).

The secondary data source is the Mexican Health and Aging Study (MHAS), designed as a harmonized sister study to the US HRS. The MHAS is a nationally representative longitudinal survey of older adults from rural and urban areas of Mexico over the age of 50 (Wong et al., 2017), and is partly sponsored by the National Institutes of Health/National Institute on Aging (grant number NIH R01AG018016) in the United States and the Instituto Nacional de Estadística y Geografía (INEGI) in Mexico. To facilitate cross-national comparisons the study has adopted protocols and survey instruments that are highly comparable to the US HRS, providing measures of the social, economic, physical, and psychological well-being of older Mexicans. To construct my analytic sample, I used the 2012 baseline survey appended with data from the MHAS biomarker files, which was the first wave to include a physical examination and blood samples for a subset of the original cohort (MHAS, 2018). The baseline survey also includes mortality follow-up through December 31, 2015. My eligible sample from MHAS consists of all primary respondents in the 2012 cohort who also participated in the biomarker examination (n = 1,766). Exclusions were made for individuals who did not have complete MetS information (n = 126), creating a final analytic sample of 1,640 individuals (92.9% of eligible sample). The MHAS sample represents a balanced panel with each respondent contributing one set of observations on the key biomarker exposure variables. I transformed the original data structure into long form person-year data files resulting in a final MHAS sample of 1,640 Mexicans in Mexico representing 12,249.2 person years at risk and 108 deaths.

In preparation for joint analysis, I appended the two data sources—the HRS biomarker sample (2006-2014) with mortality follow-up through 2019 and the MHAS biomarker sample (2012) with mortality follow-up through 2015—and applied probability weights to yield estimates representative of the non-institutionalized populations of older adults over the age of 50 living in the US and Mexico.

Study Measures

Sociodemographic characteristics. To define the key study populations, I used self-reported race/ethnicity, nativity status, and country of origin measures from the HRS to define the three US study populations of interest: US-born non-Hispanic whites (hereafter, US-born whites), US-born Mexican Americans, and foreign-born Mexicans in the US. The fourth study population, Mexicans living in Mexico, come from the MHAS sample.

Exposures. The main exposure for this study was meeting the clinical definition of metabolic syndrome (MetS). To construct a measure of MetS, I adopted the worldwide consensus definition from the International Diabetes Federation (Alberti et al., 2006), which defines MetS as the presence of central adiposity alongside two or more additional metabolic conditions out of impaired fasting glucose (HbA1c > 5.7%), dyslipidemia (HDL-C <40 mg/dL for males or <50mg/dL for females), and hypertension (SBP ≥ 130mmHg, DBP ≥ 85 mmHg).

The presence of central adiposity was determined by either the categorization of obesity (BMI ≥ 30 kg/m^2) or a waist circumference ≥ 108 cm for males or ≥ 88 cm for females. A dichotomous measure (0/1) was made for each component as well as a summary indicator of MetS (0/1).

Outcome. The main outcome was mortality. For the HRS sample, mortality data was obtained through individual-level linkage to the National Death Index (NDI). For the MHAS sample, mortality data was obtained through the household-level follow-up files.

Covariates. All statistical models were adjusted for time-invariant covariates that may differentially influence the risk of both metabolic syndrome and mortality across the study populations, including: age (centered at 50 years-old), sex, education (less than upper secondary, upper secondary and vocational, and tertiary), years spent smoking up to age 50, and calendar year.

Analysis

All analyses were weighted and conducted in Stata/MP-2 17.0 and standard errors were clustered at the individual sampling level to maintain the independence assumption across individuals, but not observations, given that multiple observations per respondent are possible in the HRS sample (StataCorp, College Station, Texas, USA). I estimated unadjusted proportions and means for the metabolic health exposures, covariates, and mortality outcomes for each study population. To account for differences in age structure across each of the study populations, I also present age-standardized prevalence rates for each of the five metabolic conditions and MetS overall using direct standardization to the 2010 US Census population age distribution.

For the main set of analyses, I fit a multivariate complementary log-log regression discrete-time hazards model to estimate the mortality risks of MetS and each of the component conditions. In addition to adjusting for the full set of covariates in the hazards model, I include interactions for MetS/metabolic condition x race-ethnicity/nativity/country of residence group and education x race-ethnicity/nativity/country of residence group to account for expected differences in associations by study population. An age^2 term was also included to account for the curvilinear association between age and mortality. From the same underlying multivariate hazards model, I calculate population attributable fractions (PAFs) for MetS, each of the key component conditions, as well as smoking history to compare and contextualize how metabolic disparities across study populations differentially contribute to mortality risks. All tests were two-sided and significance was considered at $P < 0.05$ for all analyses.

RESULTS

Descriptive statistics

Table 4-1 summarizes the weighted study characteristics and outcomes across each of the four study populations. US-born whites and Mexicans living in Mexico were the oldest groups, with mean ages of 65.3 and 64.7 years old, and US-born Mexican Americans and Mexican immigrants were approximately 4.5 years younger on average with mean ages of 61.6 and 61.1 years old. The mean year of interview fell between 2012-2013 for all groups, with the latest interviews occurring midway through 2013 on average for Mexicans living in Mexico. The group of Mexican immigrants to the US were composed of the most males at 52.3%, while Mexicans still living in Mexico represented the lowest proportion of males at 45.3%. US-born whites received the highest levels of education, with the highest proportion receiving a tertiary education and the lowest proportion ending their education below the upper secondary or vocational levels. Mexicans living in Mexico had the lowest levels of educational achievement, while Mexican immigrants to the US received tertiary education at higher levels than US-born

Mexican Americans yet also had a higher proportion ending their education below the upper secondary level. The US-born groups spent the most years smoking, with whites averaging 13.3 years before the age of 50 and Mexican Americans 16.4 years, while Mexican immigrants to the US smoked for 9.6 years on average and Mexicans still living in Mexico averaged 8.9 years. Patterns of metabolic conditions and MetS overall were not meaningfully altered by differences in age structure across the groups. Mexicans living in Mexico had significantly higher rates of MetS as compared to all other groups, with age-standardized prevalence of 50.1% versus 32.6% and 32.3% for US-born Mexican Americans and Mexican immigrants to the US, respectively, and the lowest prevalence of 23.5% for US-born whites. Despite the prominent role that obesity and high waist circumference play in determining the presence of MetS under the International Diabetes Federation's classification standards (Alberti et al., 2006), Mexicans living in Mexico had the lowest rates of obesity and shared the lowest levels of high waist circumference with Mexican immigrants to the US as compared to the US-born groups. However, Mexicans living in Mexico had significantly higher rates of high blood pressure, low HDL cholesterol, and pre-diabetic or diabetic levels of elevated blood glucose as compared to all other groups. Consistent with the Hispanic paradox in mortality and healthy immigrant selection theories (Markides & Coreil, 1986; Markides & Eschbach, 2005; Riosmena et al., 2013), Mexican immigrants to the US represented the smallest proportion of deaths during the follow-up period.

Multivariate discrete hazards model

In Table 4-2 I summarize the results of the multivariate complementary log-log regression discrete-time hazards model predicting mortality associated with elevated blood glucose levels. Separate survival models were fitted for each metabolic condition and MetS overall (see Tables C-1 through C-5 in the appendix), yet elevated blood glucose was the only condition found to significantly increase mortality risk, so I focus on pre-diabetes and diabetes—or, elevated blood glucose—when reporting the main set of analyses. The model reveals that for every point above the prediabetic threshold (A1c of 5.7%) an individual's risk of death increases by 15% (HR 1.15, 95% CI 1.09-1.21). Age, year of survey, being male, and increased years spent smoking were all also significant predictors of increased mortality risk. Higher levels of education were predictive of lower mortality risk, with the exception of a significant interaction in the model indicating that Mexicans living in Mexico who achieved tertiary levels of education experience heightened rather than reduced risk of mortality compared to lower educational categories. Consistent with prior research on older Hispanics in the US (Lariscy et al., 2015), there is no evidence of a significant Hispanic mortality advantage in this sample, with all groups facing statistically similar mortality risks after controlling for sociodemographic factors. There was also no evidence in any of the models of a difference in the mortality risk associated with MetS or the individual metabolic conditions across the four study groups defined by race-ethnicity/nativity/country of origin, and thus, that interaction term was dropped from the final models.

Population attributable fractions (PAFs)

The population attributable fractions (PAFs) summarized in Figure 4-1 are based on the underlying hazards model. The PAFs can be interpreted as the percentage of deaths in each population that is attributable to the exposure. The figure presents two exposures for each of the four study populations. The primary exposure of interest is elevated blood glucose levels (dark gray bar), which is contextualized against the effect of smoking (light gray bar) given the known strength of the association between smoking and increased mortality risk and the prominent role it has historically played in explaining the Hispanic paradox (Blue & Fenelon, 2011; Fenelon, 2013). The results reveal that lowering fasting blood glucose to below pre-diabetic levels would proportionally reduce the associated mortality burden for older Mexicans (10.9%, 95% CI 7.6-14.1%), Mexican immigrants (14.9%, 95% CI 10.0-19.6%), and US-born Mexican Americans (10.7%, 95% CI 7.4-13.8%) significantly more than it would for US-born whites (3.8%, 95% CI 2.7-4.9%). Moreover, the proportion of mortality attributable to smoking was significantly higher for US-born whites (32.7%, 95% CI 28.6-36.5%) and Mexican Americans (34.9%, 95% CI 30.6-38.9%) than it was for Mexicans living in Mexico (20.6%, 95% CI 18.1-23.1%). The smoking attributable mortality was also significantly higher for US-born Mexican Americans than it was for Mexican-born immigrants to the US (26.0%, 95% CI 22.7-29.1%), but the difference in smoking attributable mortality between US-born whites and Mexican immigrants to the US did not reach a level of statistical significance.

DISCUSSION

In this paper I first aimed to determine the current distribution of metabolic health conditions across Mexican-origin populations in the US and in Mexico as compared to US-born whites and US-born Mexican Americans. I found that Mexicans living in Mexico had significantly higher rates of MetS as compared to all other groups, which was not driven by differences in the primary determining metabolic conditions of obesity and waist circumference, but instead by large disparities in high blood pressure, low HDL cholesterol, and pre-diabetic or diabetic levels of blood glucose levels. Mexican immigrants to the US also showed a typical Hispanic health advantage in obesity and high waist circumference over US-born whites, yet were disadvantaged in terms of high blood pressure, low HDL cholesterol, and blood glucose levels. In contrast, out of all the groups, US-born Mexican Americans had the highest rates of obesity and high waist circumference, yet fared the same or better than Mexican immigrants to the US and Mexicans living in Mexico on blood pressure, cholesterol, blood glucose, and MetS overall.

This represents the first study to present a detailed breakdown of the distribution of MetS and its components across older Mexican-origin populations in the US and Mexico using the only available data sources that could permit such an analysis: a harmonized, cross-national dataset of HRS-MHAS combining both the origin and destination countries in a joint analysis with the most recent available waves of data from each source. This descriptive analysis, as a standalone contribution, offers a couple key takeaways that may inform and guide future research efforts and potential interventions to improve the health and mortality prospects of Mexican-origin populations in the US, and the US population overall, as these groups are featured centrally in the twin processes of population diversification and aging that will significantly reshape US demography over the next few decades.

First, while this study was unable to directly interrogate whether routine healthcare access and health insurance coverage could explain the disparities between US-born groups and Mexican-born groups in physiological metabolic conditions that are known to respond well to pharmacological treatment (Rask Larsen et al., 2018),[3] prior research documenting immigrant-native disparities in healthcare access confirm this is likely an important, though partial, explanation (Brown, 2018). Second, the finding that Mexican-origin populations faced a

[3] The only common measure of healthcare access available across HRS and MHAS surveys was a self-reported response to the question ‘have you seen a doctor in the last 1-2 years?’. However, there was not sufficient variation in response distributions within and across groups to include this measure in the analytic models.

disadvantage on physiological metabolic conditions while maintaining an advantage on anthropometric measures also reinforces the notion that at older ages body weight composition and BMI may become unreliable indicators of overall health and mortality risk due to the greater likelihood of bias from high levels of co-morbidities and associated changes in body composition (Mehta & Chang, 2011). As such, this study supports the idea that greater attention should be paid in middle-aged and older adult populations to managing the remaining physiological metabolic indicators—including blood pressure, cholesterol, and especially, blood glucose levels—that are more directly associated with the heightened risk of mortality and health complications stemming from diabetes and cardiovascular disease (Mazloomzadeh et al., 2019; Shi, 2020; van Herpt et al., 2016). This finding is also reinforced by evidence from an earlier study based on MHAS data, which found that obesity has a strong total effect on mortality in the older Mexican population, with an estimated reduction in life expectancy beyond age 50 of 1-2 years, driven primarily by the influence of diabetes (Palloni et al., 2015).

In the next phase of analysis, I sought to determine if the reported differences in the distribution of metabolic health conditions discussed above translate into significant differences in associated population attributable mortality risks across the four study populations. I focus on the outcome of elevated blood glucose, as it was the only condition found to be a significant predictor of increased mortality risk. The results did reveal significant differences in the proportion of mortality in each group that could be attributed to elevated blood glucose. The main takeaway from this analysis is that lowering fasting blood glucose to non-diabetic levels would proportionally reduce the associated mortality burden for older Mexicans, Mexican immigrants, and US-born Mexican Americans significantly more than it would for US-born whites, and thus should be a central target in any effort to preserve and promote the health and longevity of Mexican-origin populations in the US.

Overall, these results remain consistent with the disparities in pre-diabetes/diabetes prevalence across groups reported in the descriptive analysis, but additionally reflect the intensity of those disparities—that is, the degree to which blood glucose is elevated above the prediabetic threshold in each group—thereby translating into heightened mortality risk net of sociodemographic factors. Differential access to healthcare services and resources is another set of closely related factors that could influence not only the disparities in prevalence discussed above, but also differences in the proportion of mortality attributable to pre-diabetes and diabetes for each group. Notably, prior research has also emphasized the importance of expanded healthcare access to monitor and manage diabetes, as it has become a primary driver of preventable mortality among Mexican-origin populations living in Mexico and the United States (García Pérez et al., 2021; Pagán & Puig, 2005). As previously mentioned, I was unable to explore the influence of such healthcare services and systems-level factors in sufficient granularity in the present study due to data limitations. However, the results reported here placed in dialogue with the existing literature all signal in the same direction, highlighting the need for increased research attention on this issue and for providing affordable access to insurance, preventive services, and blood glucose monitoring and management resources for older Mexican-origin populations in the United States to promote extended periods of health and longevity.

This analysis also revealed differential educational gradients in the mortality risks attributable to prediabetes/diabetes, with Mexicans living in Mexico who achieved tertiary levels of education experiencing heightened rather than reduced mortality risks as compared to those with lower levels of formal education. This finding is consistent with prior research on the Mexican population and Mexican-origin population in the US displaying a surprisingly weak gradient between educational achievement and obesity prevalence (Buttenheim et al., 2013; Goldman et al., 2006), and at least some evidence of obesity levels increasing with rising educational levels in Mexico due to increased consumption of alcohol and sugar-sweetened beverages (Fernald, 2007).

In the final phase of analysis, I sought to contextualize how bringing blood glucose levels below the pre-diabetic threshold would compare to eliminating lifetime smoking histories up to age 50 in each of the groups. This comparative analysis revealed that the effect of controlling blood glucose levels for Mexican immigrants to the US and Mexicans living in Mexico would be comparable in effect to cutting the average number of years spent smoking up to the age of 50 by more than half for both groups—or, eliminating roughly 4-5 years of smoking history. Although the comparison between controlling blood glucose levels and eliminating smoking histories was not as stark for US-born Mexican Americans, roughly translating to cutting down the years spent smoking prior to age 50 by one-third, the overall effect of controlling their blood glucose would similarly translate to eliminating more than 5 years of smoking history. In contrast, the proportion of deaths attributable to smoking was roughly nine-times that attributable to elevated blood glucose levels for US-born whites, making the effect of controlling blood glucose comparable to eliminating only a little over a year of smoking history prior to the age of 50 for this group. These comparisons help to demonstrate the magnitude of the potential effect that controlling elevated blood glucose levels could have on reducing disparities not only in pre-diabetes/diabetes prevalence between US-born whites and first- and later-generation Mexican immigrants, but also on reducing overall inequities in later-life morbidity and mortality.

These findings lend greater empirical support to the suspicion that diabetes could emerge as the preeminent mortality threat for Mexican immigrants to the US later in life despite their historical mortality advantage. Prior research has concluded that Hispanics' mortality advantage over non-Hispanic whites has been primarily driven by more favorable smoking behaviors (Blue & Fenelon, 2011; Fenelon, 2013). Yet as Hispanics now face increasing vulnerabilities to health problems related to obesity and diabetes, and the gaps in smoking behaviors have begun to narrow between Hispanics and non-Hispanics, the question has been raised as to whether the Hispanic mortality advantage will erode or persist in the future (Goldman, 2016). The results of the only two published studies that have empirically evaluated this question (Frisco et al., 2019; Van Hook et al., 2020), alongside the findings of the present study, all collectively support the conclusion that the more favorable smoking profile of Mexican-origin populations is likely preserving their current mortality advantage over US-born groups despite disadvantages in terms of obesity and associated metabolic health complications. However, the results of the present study uniquely highlight substantial imbalances that have emerged in the proportion of overall mortality that can be attributed to diabetes among a current cohort of older Mexican Americans, Mexican immigrants, and Mexicans in Mexico as compared to US-born whites. Given that older Hispanics have already lost their comparative mortality advantage in the US (Lariscy et al., 2015), it will be crucial to identify and institute effective interventions through policy and practice to help prevent and control diabetes as a major source of preventable mortality among older Hispanics at a time when they are growing as a share of the US Hispanic population overall.

While this study offers significant contributions to the literature on the current and future health and mortality prospects of older Mexican-origin populations, the results and their interpretation must be considered within study limitations. The primary limitation in this analysis, as discussed in greater detail above, is the lack of granular healthcare and health access variables shared across both datasets. It is also possible that a lack of statistical power due to small sample sizes prevented the detection of a significant interaction in the mortality risk presented by MetS and the individual component conditions across each of the four study populations, which could have partially captured differences in treatment and ongoing care in the absence of additional healthcare variables. Another significant limitation was the inability to model outcomes separately for males and female given the relatively small sample of US-born Mexican Americans and Mexican immigrants to the US who were represented in the HRS. As permitted by the availability of alternate data sources or larger HRS-MHAS samples as additional waves are released, future research should attend to the questions left unanswered by this study about the role that access to healthcare services could play in explaining disparities in the prevalence, intensity, and proportion of deaths attributable to elevated blood glucose between US-born and Mexican-origin groups, as well as whether or not the patterns reported here differ significantly between males and females.

CONCLUSION

In sum, there are significant disparities in the distribution of metabolic conditions and attributable mortality across older Mexican-origin populations as compared to US-born whites and future research and preventive efforts should focus on the role of diabetes in rising mortality risks, especially in aging cohorts.

Table 4-1. Weighted study characteristics and outcomes by race-ethnicity, nativity, and country of residence: Older adults in the Health and Retirement Study (HRS, 2006-2014) and the Mexican Health and Aging Study (MHAS, 2012) (*N* = 13,866)

	US-born (HRS)		Mexican-born (HRS + MHAS)	
Characteristics	Non-Hispanic whites (*N* = 10,977)	Mexican Americans (*N* = 538)	Mexican immigrants to US (*N* = 711)	Mexicans living in Mexico (*N* = 1,640)
Age, [mean (SE)]	65.3†‡ (0.06)	61.6*‡§ (0.18)	61.1*†§ (0.16)	64.7†‡ (0.32)
Year, [mean (SE)]	2012.1†‡§ (0.02)	2012.5*‡§ (0.08)	2012.7*†§ (0.08)	2013.5*†‡ (0.05)
Sex, male [%]	48.9‡§	48.6	52.3*§	45.3*‡
Education [%]				
Less than upper secondary	8.1†‡§	24.6*‡§	37.5*†§	89.0*†‡
Upper secondary/vocational	61.2†‡§	59.3*‡§	34.8*†§	3.5*†‡
Tertiary	30.7†‡§	16.1*†§	27.7*†§	7.5*†‡
Smoking, years spent up to age 50 [mean (SE)]	13.3†‡§ (0.09)	16.4*‡§ (0.45)	9.6*† (0.35)	8.9*† (0.63)
High-risk metabolic health indicators, unadjusted [%]				
Obesity	40.5†§	51.0*‡§	37.9†	35.0*†
High waist circumference	62.9†‡§	70.6*‡§	54.3*†	57.2*†
High blood pressure	45.2†‡§	53.5*§	50.3*§	65.4*†‡
Low HDL cholesterol	28.7†‡§	29.7*‡§	36.2*†§	68.5*†‡
Pre-diabetes	37.9†‡§	52.8*§	54.7*§	75.3*†‡
Metabolic syndrome, central adiposity (obese or non-obese with high waist circumference) and ≥ 2 high-risk health indicators	24.4†‡§	34.8*§	33.2*§	50.5*†‡
High-risk metabolic health indicators, age-standardized [%]				
Obesity	40.5†‡§	47.2*‡§	35.2*†	35.1*†
High waist circumference	62.3†‡§	69.5*‡§	52.8*†	56.6*†
High blood pressure	45.0†‡§	53.2*§	52.0*§	65.2*†‡
Low HDL cholesterol	28.5‡§	30.0‡§	35.1*†§	68.8*†‡
Pre-diabetes	36.2†‡§	51.1*§	54.4*§	75.0*†‡
Metabolic syndrome, central adiposity (obese or non-obese with high waist circumference) and ≥ 2 high-risk health indicators	23.5†‡§	32.6*§	32.3*§	50.1*†‡
Died during follow-up [%]	3.6‡	3.0‡	1.2*†§	3.2‡

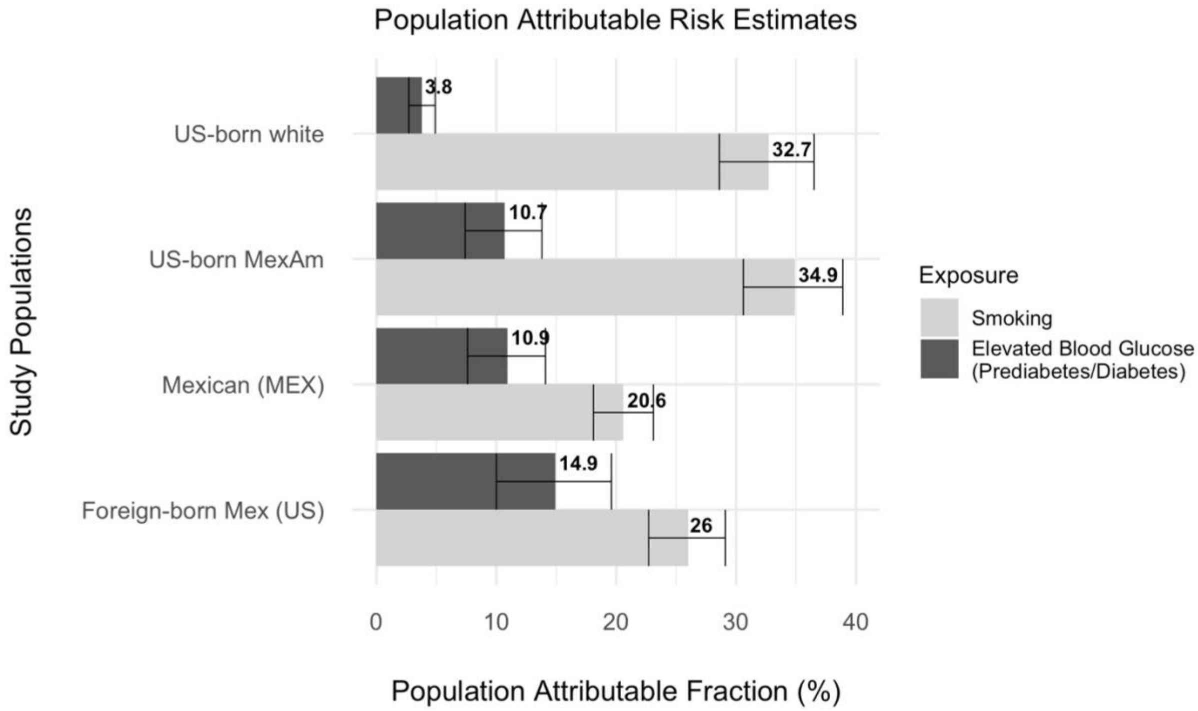
Notes. Weighted descriptive statistics. Symbols indicate a statistically significant difference at the $\alpha = 0.05$ level in proportions/means between the respective group in each column and US-born non-Hispanic whites (*), US-born Mexican Americans (†), Mexican immigrants to the US (‡), and Mexicans living in Mexico (§).

Table 4-2. Elevated blood glucose and mortality risk: Older adults in the Health and Retirement Study (HRS, 2006-2014) and the Mexican Health and Aging Study (MHAS, 2012) (*N* = 13,866)

	HR	95% CI
Elevated blood glucose levels, A1c centered at prediabetic threshold (5.7%)	1.15***	(1.09, 1.21)
Racial-ethnic/nativity/country of residence disparity (reference = US-born white)		
US-born Mexican American	1.20	(0.73, 1.97)
Mexican immigrant to US	0.62	(0.29, 1.29)
Mexican living in Mexico	0.78	(0.53, 1.14)
Age, centered at 50	1.03*	(1.00, 1.06)
Age^2	1.001***	(1.001, 1.002)
Year	1.02*	(1.00, 1.04)
Sex, male	1.32***	(1.15, 1.50)
Education (reference = less than upper secondary)		
Upper secondary/vocational	0.77**	(0.64, 0.92)
Tertiary	0.52***	(0.41, 0.66)
Smoking, years spent up to age 50 [mean (SE)]	1.02***	(1.02, 1.03)
Interactions		
Education x race-ethnicity/nativity/country of residence		
Upper secondary/vocational x US-born Mexican Americans	0.61	(0.28, 1.33)
Upper secondary/vocational x Mexican immigrant to US	0.46	(0.16, 1.38)
Upper secondary/vocational x Mexican living in Mexico	0.49	(0.06, 3.70)
Tertiary x US-born Mexican Americans	2.25	(0.65, 7.80)
Tertiary x Mexican immigrant to US	0.74	(0.19, 2.95)
Tertiary x Mexican living in Mexico	4.07**	(1.71, 9.67)

Notes. Results based on complementary log-log regression with exponentiated coefficients. Hazard ratios (HR) and 95% confidence intervals (CIs) reported. $*P < .05$, $**P < .01$, $***P < .001$.

Figure 4-1. Population attributable fractions of elevated blood glucose levels as compared to smoking by race-ethnicity, nativity, and country of residence: Older adults in the Health and Retirement Study (HRS, 2006-2014) and the Mexican Health and Aging Study (MHAS, 2012) (*N* = 13,866)



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Chapter 5 – Conclusion

INTRODUCTION

This dissertation explored current and future health and mortality patterns among the US Hispanic population with a specific focus on implications for the Hispanic paradox. It has been a number of years since questions were first prominently raised in the scientific literature about how trends in obesity might impact the longstanding Hispanic mortality advantage (Goldman, 2016; Hummer & Hayward, 2015), but to date, few empirical studies have directly addressed this issue. As such, this dissertation has drawn heavily on the methods and perspectives of demography in attempt to further our knowledge in this area. Taking up three aligned lines of inquiry that represent critical gaps in our current understandings and expectations for the future, Paper 1 focused on the Hispanic health advantage in metabolic syndrome among recent and later immigrants, Paper 2 projected future obesity levels for US- and foreign-born Hispanics and US-born whites to assess future impacts to mid-life life expectancy and the potential reshaping of US mortality patterns, and Paper 3 used cross-national data on older adult populations to explore the current distribution of metabolic conditions and associated mortality risks across Mexican-origin populations in the US and Mexico to better understand the areas of greatest vulnerability for older adults. Separately, and in tandem, each of these studies provides insights into current and future health and mortality patterns for the US Hispanic population at a moment when Hispanics feature prominently in major demographic processes affecting the composition of the US population, including immigration, diversification, growth, and aging. This final chapter of the dissertation will review and highlight key findings from each of the three papers before discussing broader implications for this work and future directions that may open up as current limitations are addressed.

OVERVIEW OF PAPERS

Paper 1 – Mexican Immigrant Health Advantage in Metabolic Syndrome? Decomposing the Effects of Demographic, Socioeconomic, and Health Behavior Characteristics

Although Mexican immigrants to the United States (US) have historically held some of the largest and most consistent health and mortality advantages over US-born groups (Antecol & Bedard, 2006; Markides & Eschbach, 2005), the convergence of cross-border epidemiological trends of rising obesity levels, evolving population dynamics in Mexico, and shifts in Mexico-US immigration patterns and policy regimes has raised new concerns about the metabolic health of recent cohorts of Mexican immigrants. Using a nationally representative sample of adults from the National Health and Nutrition Examination Study (NHANES, 1999–2016), Paper 1 of the dissertation assessed and sought to explain differences in metabolic syndrome (MetS) risk by race-ethnicity, country of origin, and duration of residence in the US to evaluate whether recent Mexican immigrants continue to exhibit a metabolic health advantage. I found that recent Mexican immigrants do still hold a metabolic health advantage over earlier Mexican immigrants, US-born Mexican Americans, and US-born whites, but it is currently only being upheld by their relative youth. This finding aligns with that of other studies that have previously found Hispanics' metabolic health advantage over other racial-ethnic groups in the US can be explained by age and other basic demographic characteristics (Boen & Hummer, 2019; Crimmins et al., 2007; Zhang et al., 2012). Yet the replication of this finding with more recent data and an explicit focus on recent Mexican immigrants—traditionally the most health advantaged subpopulation in the US (Cho et al., 2004)—is notable, and underscores the need for explicit social and policy solutions to preserve and protect the health of all US Hispanics, and particularly, newly-arriving immigrants.

To this end, I then sought to better understand the possible avenues by which social policy interventions could be leveraged to safeguard the metabolic health of newly-arrived Mexican immigrants to the US. I employed a decomposition analysis of the disparity in MetS prevalence between US-born whites (45.5%) and recent Mexican immigrants (29.5%) to determine how demographic, socioeconomic, and health behavior characteristics contribute to the current patterning of metabolic health between these groups. This analysis revealed that recent Mexican immigrants would retain a sizable age-adjusted MetS advantage if they were to achieve parity with US-born whites on education, income, and food security. As such, a key and actionable takeaway from Paper 1 is that promoting health equity on measures of metabolic health across racial-ethnic and nativity groups will require focusing on policies that would help to resolve immigrant-native disparities on these socioeconomic metrics, such as equitable pathways to citizenship and robust worker protections.

Paper 2 – Erosion of the Hispanic Paradox? Projecting the Effects of Obesity on Future Life Expectancy in the US

Responding to similar concerns about recent trends in obesity disproportionately affecting Hispanics in the US, Paper 2 of the dissertation looked ahead to directly estimate future obesity levels and the expected impact on mortality patterns by race-ethnicity and nativity in the US. For this study, I leverage data from NHANES (1988-2014 with mortality follow-up through 2015) supplemented with additional data from the National Health Interview Survey (NHIS, 1989-2014 with mortality follow-up through 2015), the American Community Survey (ACS, 2015), US life tables from the National Center for Health Statistics (NCHS, 2015), and population projections from the US Census. I use and combine information from each of these population data sources to project the impact of observed patterns in obesity prevalence among non-Hispanic whites and US-born and foreign-born Hispanics on age-40 life expectancy (e_{40}) three decades into the future. I first aimed to project what obesity distributions will look like for male and female US-born Hispanics, foreign-born Hispanics, and US-born whites over the next three decades, beginning with a cohort of adults living in the US in 2015. I found that despite having the highest distributions of obesity at baseline, projected future trends in obesity for US-born Hispanics are expected to follow a similar pattern to whites overall; a finding consistent with the recent narrowing of obesity disparities between US-born whites and Hispanics (Flegal et al., 2016; Hales et al., 2020). The projections of future obesity distributions also revealed a typical pattern of immigrant health advantage among foreign-born Hispanics, as they started with the lowest levels of class II/III obesity in 2015 and were generally projected to have the most limited growth in this higher-risk category through 2045.

My second aim was to estimate the impact of these shifting obesity distributions on future life expectancy over the next three decades to evaluate whether the Hispanic paradox in mortality is expected to persist or erode. Overall, I found that the expected impact of changes in obesity on future life expectancy are generally lower for males than females, and across racial-ethnic/nativity groups, are expected to be smallest for foreign-born Hispanics and the largest for US-born Hispanics, followed closely by US-born whites. Somewhat counter to the expectations I had set based on historical trends and the few existing studies on this topic (Frisco et al., 2019; Van Hook et al., 2020), I ultimately found that obesity is expected to have a large and comparable effect on US mortality for all groups, and thus is unlikely to significantly reshape the existing Hispanic advantage in life expectancy within the foreseeable future. However, despite the lack of evidence of a significant reshaping of US mortality patterns by race-ethnicity/nativity spurred by recent obesity trends, it is worth emphasizing that obesity is still expected to impose a significant penalty on future life expectancy gains over the next several decades in the range of 31-50% for males and 44-73% for females. This is a clear indication of the potential for obesity to significantly negatively impact US mortality for years to come, and a reminder of the importance of identifying comprehensive and preventive solutions to promote the health and longevity of the entire US population.

Paper 3 – Metabolic Health and Mortality Among Older Hispanics in the US and Mexico: Focusing on the Role of Diabetes

Paper 3 shifts focus to later life and extends the geographic scope of the dissertation by combining cross-national samples of older adults from both the US Health and Retirement Study (HRS, 2006-2014 with mortality follow-up through 2019) and Mexican Health and Aging Study (MHAS, 2012 with mortality follow-up through 2015) in a single, harmonized dataset. Using this novel data source, I first aimed to determine the current distribution of metabolic health conditions across Mexican-origin populations in the US and Mexico as compared to US-born whites and US-born Mexican Americans. Despite much of the existing attention and early discourse around this topic area being dedicated to disparities in anthropometric components of MetS—such as, obesity and elevated waist circumference—the findings of Paper 3 help to highlight that in older populations it is the physiological components of MetS—such as, high blood pressure, low HDL cholesterol, and especially elevated blood glucose (i.e., pre-diabetes/diabetes)—that are currently driving disparities in both metabolic health and associated mortality risks between Mexican-origin populations on both sides of the border and US-born whites. This finding signals the need to further interrogate the role that access to primary and routine healthcare services, as well as medical insurance coverage, plays in explaining observed disparities, particularly since it is precisely these physiological metabolic conditions that are typically considered to be the most readily treatable through pharmacological intervention (Rask Larsen et al., 2018). This finding also aligns with prior research suggesting that at older ages body weight composition and BMI become increasingly unreliable indicators of overall health and mortality risk due to bias introduced from high levels of co-morbidities and associated changes in body composition (Mehta & Chang, 2011). Taken together, these findings signify that greater attention should be paid in middle-aged and older Hispanic populations to managing physiological metabolic indicators—including blood pressure, cholesterol, and especially, blood glucose levels—that are more directly associated with the heightened risk of mortality and health complications stemming from diabetes and cardiovascular disease (Mazloomzadeh et al., 2019; Shi, 2020; van Herpt et al., 2016).

I next sought to determine if these observed disparities in the distribution of metabolic health conditions are also reflected in significant differences in associated population attributable mortality risks across Mexican-origin and US-born populations. I focused this analysis on the outcome of elevated blood glucose (i.e., prediabetes/diabetes), as it was the only condition found to be a significant predictor of increased mortality risk. I found significant differences in the proportion of mortality in each group that could be attributed to elevated blood glucose, meaning that lowering fasting blood glucose to non-diabetic levels would proportionally reduce the associated mortality burden for older Mexicans, Mexican immigrants, and US-born Mexican

Americans significantly more than it would for US-born whites. The key takeaway from this analysis is that preventing and controlling diabetes should be a central target in any broader efforts to preserve and promote the health and longevity of aging Mexican-origin populations in the US. To underscore the potential impact of interventions in this area, I conducted an additional comparative analysis, which revealed that the effect of controlling blood glucose levels for Mexican immigrants to the US and Mexicans living in Mexico would be roughly equivalent to cutting the average number of years spent smoking up to the age of 50 by more than half for both groups—or, eliminating roughly 4-5 years of their overall smoking history.

IMPLICATIONS

Implications for population health

Each of these studies has offered key insights into the role that obesity and related metabolic conditions could play in reshaping health and mortality patterns among the US population in coming decades, with a specific focus on expected consequences for the longstanding Hispanic mortality advantage. Moreover, each chapter of the dissertation has been organized to address this overarching question while remaining attuned to key demographic processes—namely immigration, population change, and aging—that will ultimately impact the future composition of the US Hispanic population and overall health and mortality patterns relative to other US population groups going forward. Taking advantage of this framing, I have found it particularly useful to imagine how the current implications of this research, with respect to the demographic processes and groups that are centered in each study, may wax and wane as expected demographic futures play out.

The main takeaway from Paper 1 was that the Mexican immigrant health advantage in metabolic syndrome will likely be lost for future immigrants, particularly with increasing time spent in the US, if greater action is not taken to open up pathways for economic security and educational advancement for both first-generation immigrants and their offspring that are on par with the resources and opportunities available to US-born whites (Chapter 2/Carabello & Wolfson, 2021). This finding is particularly noteworthy, as it is precisely this demographic group of young first-generation Mexican immigrants within their first decade of residence in the US who have historically held the strongest health and mortality advantages (Cho et al., 2004), largely driving the advantaged pattern attributed to Hispanics as a group overall. But, as was briefly discussed in Paper 1, evidence of the precarity of this longstanding pattern extends beyond the findings of my own research and is further reinforced by contextual evidence regarding shifts in the nature of Mexico-US immigration, as well as in epidemiological trends towards higher weight and poorer metabolic health outcomes on both sides of the border.

Within the past decade, the Mexico-US immigration stream has become increasingly "bipolar" (Durand, 2016)—on the one hand, characterized by a large number of undocumented migrants fleeing situations that threaten their lives and livelihoods, and on the other, by an increasing share of labor migrants who move to and from the US in circular routes responding to the fluctuating availability of temporary worker visas. In both cases, the implications with respect to the health of US immigrants are dire. As Durand and Massey (2019) describe it, the current situations faced by Mexican immigrants to the US are, "characterized by the ongoing repression of undocumented migrants north of the border combined with the ongoing exploitation of legal but temporary migrants who crisscross a heavily militarized border to work in an increasingly integrated North American labor market (p. 40)." While these shifts in the nature and experience of migrating from Mexico to the US increase the likelihood of post-migration health declines, it is also expected that the health of the initial migrant pool will continue to deteriorate, as Mexico faces its own obesity epidemic and selection on health becomes a diminishing feature in the migrant selection process.

Now, to consider the implications this potential shift in the health status and prospects of the largest immigrant group in the US might have on population health, I turn to the expected role that immigration will play in shaping the US population and society over the next few decades. According to the Congressional Budget Office's latest set of projections through the year 2053 (CBO, 2023), immigration is expected to supplant fertility as the driving force behind US population growth. This means that the health of Mexican immigrants will increasingly impact the overall US population health landscape, as they grow as a share of the young working age sector, significantly influencing both overall population dynamics and the economy. Taken together, the portrait of the current vulnerabilities to the health of young Mexican immigrants laid out in Paper 1 paired with their rising influence in shaping and growing the overall US population, only raises the import of intervening to protect and preserve their health post-migration as a pathway to greater overall population health equity.

Of the three studies in this dissertation, Paper 2 most explicitly addressed the central question at the heart of the project—that is, will obesity erode the Hispanic paradox in the future? The answer I arrived at, while nuanced, is that given significant adverse impacts on mortality across the entire US population, obesity alone is not expected to erode the Hispanic paradox or significantly reshape US mortality patterns on the basis of race, ethnicity, and/or nativity in coming decades. Given how acutely population structure and demographic processes can influence a projection-based analysis of future obesity levels, I was careful in my approach to fully stratify baseline populations by age, sex, and racial-ethnic/nativity group. I also used the most detailed available Census population projections, even accounting for expected immigration scenarios, when incorporating new cohorts of young adults into future projection periods. However, as discussed with the implications of Paper 1, it is possible that even if I was successful in closely capturing the likely size and structure of the future foreign-born Hispanic population, I may not have fully captured possible upward shifts in their weight trajectories not yet reflected in the latest waves of available data. It is possible that the more favorable weight trajectories observed among the foreign-born may begin to fall closer to those observed for US-born whites and US-born Hispanics as changes in both the health of immigrants prior to migration, as well as the health risks and vulnerabilities accumulating during and after the migration process, are captured in forthcoming waves of data. At the same time that the pattern of lower weight and fewer obesity-related complications may be attenuating among the foreign-born, the US-born share of the Hispanic population has also been increasing overall and continues to follow an upwards trajectory, with the US-born share increasing from 45% to 55.2% between 2007 and 2019 (Funk & Lopez, 2022). While these demographic trends likely would not upend the conclusions of Paper 2, they are consistent with the expectation that the overall Hispanic mortality advantage is likely to continue to narrow in coming years without explicit intervention.

The central takeaway of Paper 3 was that at older ages attention needs to shift from addressing anthropometric aspects of metabolic syndrome with an attenuating relationship to overall mortality risk, and towards controlling—and, ideally, preventing—physiological metabolic conditions that have more severe mortality consequences and are also more readily controlled through pharmacologic interventions. A key motivation for this paper was the recognition of how centrally Hispanics feature in the twin population processes of diversification and aging currently underway in the US, making it clear that any vulnerabilities faced by the rapidly growing and aging group of older Hispanics will only have greater impacts on the overall US health landscape as these demographic processes continue to play out. As such, the clear disparities around elevated blood glucose (i.e., prediabetes/diabetes) that were revealed between older first- and later-generation Mexican-origin populations as compared to US-born whites will only impact more of the US population, both as a share and in absolute numbers, if interventions are not soon made.

As a closing note, it is also worth recognizing that despite increasing effort and attention to this issue, selection into each of the survey samples I have used in this research—and, particularly the subset chosen to provide biomarkers—is not perfectly equalized across socioeconomic status, racial-ethnic/nativity group, or baseline health status. This selection bias, of course, has implications for interpreting the results and implications I have presented. As such, I consider the vulnerabilities exposed around the current and future health of Hispanic subpopulations and the implications I have articulated in terms of the potential effects on population health to be conservative estimates, as those not selected or unable to participate in the survey procedures likely face greater social and health disadvantages as compared to those who were represented in the sample.

To summarize, as the demographic processes of immigration, population change, and aging increasingly raise the profile of Hispanics in the US and centralize their influence on overall population dynamics, the potential vulnerabilities and threats to their health stemming from obesity and related metabolic health conditions will only be magnified, increasing the total burden on the nation’s health system. But these implications for population health—across all possible demographic futures—are not immutable, and it is the role of the policy sphere to respond to current evidence and make interventions to improve expectations for the future. Cutting across each of these implications for various segments of the US Hispanic population, I consider a vast body of work oriented around addressing racial-ethnic health disparities in the US to advocate for a framework and approach for developing a comprehensive policy response to the findings outlined in this dissertation that will most equitably and efficaciously improve US population health moving forward.

Implications for policy

In the first paper of the dissertation, I modeled and then discussed how social policy interventions in specific areas could improve the current and future metabolic health trajectories of recent Mexican immigrants to the US. While the remaining studies lacked this explicit policy focus, I will close out this section of the dissertation by discussing how a unifying orientation for resolving racial and socioeconomic health disparities through upstream social policy interventions could prove effective in responding to the population health implications from each study in the dissertation—namely, in preventing accumulating metabolic health risks for newly-arrived immigrants with increasing time spent in the US, reducing obesity levels in early- and mid-life, particularly for US-born Hispanics, and in controlling blood glucose levels in older Hispanics to prevent elevated rates of diabetes and associated mortality risks. Within the field of sociology, two main paths have emerged to guide the study and resolution of population health disparities: the *psychosocial risk factor approach* and the *fundamental cause approach*. To present a policy framework that could effectively respond to the implications discussed across my dissertation findings, I will briefly summarize and compare these two main approaches, emphasize the strengths and limitations of each, and make my case for the approach that seems best positioned to resolve current and emergent disparities in health and mortality risk faced by Hispanics in the US.

The psychosocial risk factor approach, stemming from the field of social epidemiology, represents the earlier of these two sociological responses to health disparities research. It focuses upon characterizing the ways by which risk factors—seen as mediators in the causal pathways linking social conditions to health—“get under the skin” and cause disease. Some of the main risk factors linked to health disparities through this approach include: acute and chronic stress, social relationships and support, psychological dispositions, and health behaviors (House, 2002). Over the past half century, this work has proven instrumental in challenging the once dominant biomedical model—characterized by the doctrine of specific etiology (i.e., the attribution of a disease to a specific microbiologic or physiologic cause; cf. Dubos, 1959)—to instead highlight the social determinants and patterning of disease. For example, House and colleagues (1988) note that the strength of evidence now linking the risk factor of weak social relationships to poor health outcomes has come to approximate the strength of evidence cited by the U.S. Surgeon General linking smoking to lung cancer.

As for socioeconomic and racial health disparities, specifically, the psychosocial risk factor approach focuses on identifying more proximate variables that mediate and explain the relationship between these forms of inequity and disparate health outcomes. For example, the cumulative experience of subsisting at a lower rung on the socioeconomic ladder or being marginalized as an immigrant to a new country can predispose individuals to chronic stress; a risk factor that has then been linked to increased allostatic load, harmful physical and mental health conditions, and a “weathering” effect most prominently shown to cause African American women's health to deteriorate in early adulthood, contributing to differential age-based infant mortality rates between races (Geronimus, 1992; McEwen & Wingfield, 2003; Pearlin, 1989; Thoits, 2010). To summarize the approach, House (2002) explains that, "[s]ocioeconomic position and race/ethnicity shape individuals' exposure to and experience of virtually all known psychosocial . . . risk factors, and these risk factors help to explain the size and persistence of social disparities in health (p.125)."

This approach comes with both strengths and limitations. A key strength of the risk factor approach to health disparities is that the mechanistic pathways can serve as a guide to direct action, at both individual and societal levels. When it comes to inspiring concrete solutions, focusing on the structural roots of health disparities (e.g., alleviating poverty or eliminating discrimination on the basis of race, ethnicity, and/or nativity) can have the effect of inspiring a lot of hand wringing and little action. By focusing instead on specific risk factors that have been causally linked or convincingly associated with health problems, both individuals and policymakers can involve themselves in approachable solutions. Yet, a key limitation to this approach is that, in practice, targeting individual risk factors has been shown to have only modest effects on lessening the health disparities to which they contribute (House, 2002). As such, the fundamental cause approach emerged in the 1990's as an alternate way to conceptualize and address health disparities by looking further upstream to the root, structural causes.

In response to the rapid growth of the psychosocial risk factor approach, Link and Phelan (1995, 2010) developed the fundamental cause approach to explain why focusing on improving proximate risk factors seems to have a modest effect on lessening the health disparities themselves. According to Link and Phelan, the central mechanism linking socioeconomic factors to differential health outcomes is the relative resource advantages of higher socioeconomic groups (in terms of knowledge, money, power, prestige, and social capital). These resources, and their inequitable distribution within a population, can be considered the “causes of causes” or “risks of risk” that shape individual health behaviors and outcomes (Link & Phelan, 2010). Their work demonstrates that groups with differential access to resources are predisposed to differential behaviors and responses, which eventually manifests in health outcomes that are socially patterned across a socioeconomic gradient.

More recently, Phelan and Link (2015) have further modified their theory to directly account for the persistence of racial health disparities, which are related to but not interchangeable with socioeconomic health disparities (Williams, 2005). They argue, primarily, that racism is a fundamental cause of racial differences in socioeconomic status, which is in turn a fundamental cause of health inequities. Further, the authors note that there is evidence that racism itself, independent of socioeconomic status, may act as a fundamental cause of health and contributor to health disparities. Thus, according to fundamental cause theory, lessening socioeconomic and racial disparities in the long-term will require upstream efforts to ameliorate these societal inequities.

As with the psychosocial risk factor approach, analyzing health disparities through the fundamental cause approach comes with both strengths and limitations. The key strength of the fundamental cause approach is that it returns focus to the root structural inequalities that have allowed health disparities between socioeconomic and racial groups to persist, even as the individual risk factors, mechanisms, and diseases themselves have shifted over time. However, while this conceptualization might offer a fuller theoretical explanation, it has some practical limitations that can make devising solutions difficult. For example, while the risk factor approach prioritizes the identification of operational variables, mechanisms, and the direction of causal pathways, the fundamental cause approach, in contrast, largely sets these issues to the side. This has resulted in some criticism. For example, the more diffuse nature of this approach fails to answer questions as to whether low socioeconomic standing is a cause or consequence of poor health, and some have interpreted it as absolving individuals of any responsibility to lower their health risks through more proximate means (e.g., shifting health behaviors, mitigating stress).

Along these lines, given the structural focus of the fundamental cause approach, the policy solutions it suggests operate at a much broader scale than those supported by a risk factor approach. However, Link and Phelan (1995) offer a number of recommendations to guide policy and breakdown the ultimate task of resolving structural inequities. These include shifting the focus of policy change away from risk factors and towards the social conditions that lead them to differentially impact certain groups of people; focusing on broader interventions that could lessen risk for multiple diseases as opposed to a specific condition; and, most importantly, to recognize that health policy is social policy—that is, that the great gains in reducing health disparities are more likely to come from devising policies to, for example, reduce immigrant-native disparities in income, food security, and education than from clinical interventions in the healthcare system to expand treatment to groups that have already accumulated greater metabolic health risks. In this sense, the policy agenda laid out in response to the findings of Paper 1 (Chapter 2/Carabello & Wolfson, 2021) can be seen to closely align with a fundamental cause approach to reducing health disparities by focusing on the structural roots of intersecting systems of stratification—including race, ethnicity, nativity, and socioeconomic status—and attending to the way these systems inequitably distribute social resources—and ultimately, life chances—throughout a population.

At its core, this dissertation has been concerned with a disparity in US life expectancy that defies traditional patterns, with Hispanics facing a socioeconomic disadvantage yet paradoxically outliving non-Hispanic whites. Recognizing that some of the strongest contributors to this phenomenon are beginning to diminish, I used the three studies in this dissertation to better understand the current patterning of emergent metabolic health risks that eventually may reverse this disparity and could cause the future patterning of life expectancy in the US to come to reflect broader social and socioeconomic hierarchies more directly. While current trends in obesity, carried through three additional decades in the projections for Paper 2, do not appear to threaten Hispanics' longstanding mortality advantage, the remaining studies in this dissertation reveal vulnerabilities in particular areas worthy of attention and intervention before they emerge as even more significant mortality threats. Focusing on key segments of the US Hispanic population—i.e., young, recent Mexican immigrants and older first- and later-generation Mexican immigrants—Papers 1 and 3 show that these groups have already lost or stand to lose their metabolic health advantage overall and in specific conditions, and older Mexican-origin populations, in particular, are already facing heightened mortality risks associated with their disadvantaged metabolic health profile. While much of this work has focused on proximate metabolic risk factors in effort to best anticipate potential mortality consequences, the solutions to reduce both the health and mortality risks that have been identified are to be found much further upstream. My own analysis focused on potential social interventions in Paper 1 supplemented with a review of policy approaches to resolving health disparities presented in this section, support my case that the most unifying policy framework for preventing and resolving some of the greatest health and mortality threats revealed through this research is in addressing their *fundamental causes*—that is, the social patterning of resources and restrictions, protection and risk, health and disease, life and death.

However, while I view the exercise of laying out an overarching approach to social and policy interventions that broadly aligns with the findings from my dissertation research as an important contribution to the scientific community, I also recognize that taking the additional step of applying the knowledge and perspective I have gained towards evaluating specific policies and existing approaches to the issues I have engaged with is also a valuable step to begin to bridge the gap between research and action. So, in this spirit, I end my discussion of policy implications by applying the general framework I have discussed above towards the evaluation of a specific, and currently controversial, health policy response that overlaps considerably with the focus of my research.

At the very time that I was finalizing my analyses and writing up the last of my dissertation findings in the spring of 2023, there was rising media and public awareness around recent updates made to the American Academy of Pediatrics (AAP) treatment guidelines for children and adolescents with obesity (Hampl et al., 2023). The focus of the heightened attention surrounding AAP's revised guidelines for the treatment of obesity in the pediatric population centered around two updates, in particular: first, the inclusion of a prescription drug, semaglutide, approved for weight loss under the brand name Wegovy; and second, newly approving bariatric surgery as a treatment option for adolescent patients (Yoguchi, 2023). These updates were made with the recognition that previous advice given to clinicians of 'watchful waiting' has fallen woefully short in curbing the rising prevalence and severity of childhood obesity in recent years, with the disease now affecting 14.4 million children and adolescents in the US, making it one of the most common pediatric chronic diseases with serious short- and long-term consequences for the health of this young population (Ogden et al., 2020; CDC, 2021). While there was little public dispute that childhood obesity is a serious public health issue that warrants a robust response, considerable concern arose around the guidance of treating obesity at such young ages through prescription medication and surgical interventions, with each approach introducing considerable risk of adverse effects and requiring significant, even permanent, lifestyle changes (Noguchi, 2023). In addition to fear over the risks imposed, there seemed to also be concern that these clinical approaches offer nothing in terms of disease prevention and would likely worsen the shame and stigma young patients face in relation to their weight (Noguchi, 2023).

There is consensus across each of my three dissertation studies, and all the background research I have drawn on to support them, that the earlier that obesity develops the greater the threat it imposes in terms of both overall health and mortality risk across the life course. As such, I share the concerns around the continued rise of obesity in the pediatric population that spurred this new guidance from AAP. Yet in terms of direction, I also share many of the publicly expressed fears that turning toward increasingly more invasive clinical measures focused more on reducing body weight than on improving overall health and wellbeing stand to introduce a whole host of new problems and risks with little to show in terms of promoting a healthier population. The AAP itself acknowledges that obesity is a complex disease with "…genetic, physiologic, socioeconomic, and environmental contributors (Hampl et al. 2023, p. 2)," and my own empirical evaluation of the contribution of social factors to the patterning of metabolic health conditions in Paper 1, paired with the fundamental cause approach to health policy that I have articulated and advocated for in the body of this section, together suggest that the greatest opportunities to prevent obesity from developing is by targeting primary interventions at the societal level rather than in clinical settings. Which is to say that making meaningful movement in reducing the prevalence of childhood obesity and mitigating related adverse consequences is unlikely to come from writing out prescriptions or performing more operations at younger ages, but instead is much more likely to result from holistic social interventions that help make affordable, nutritious meals and ample opportunities for safe recreation and play an accessible reality for every child in the country. Recommendations along these lines, focused on improving the balance between energy intake and expenditure by making modifications to children's everyday lives and social routines are far from novel. In fact, it is precisely these approaches, often addressed in school settings, that are reflected in and articulated with great specificity in places such as the World Health Organization's (WHO) report on "best buy" interventions to prevent and control obesity and other noncommunicable diseases (WHO, 2017), and also consistently emerge as the most efficacious interventions in meta-analyses of existing approaches to reducing childhood obesity in the US and across the globe (Bleich et al., 2018; Psaltopoulou et al., 2019; Wang et al., 2015). It is these forms of detailed and specific policy recommendations paired with direct evaluation of their current or potential impacts that are most critical for optimizing the chance of our policies better reflecting scientific consensus. But, along the way, and to support those efforts of synthesis, it remains important to connect the dots between isolated individual research efforts and the broader policy agendas or directions they support or refute, so that it is not for lack of clarity in the scientific record that action is not taken in the policy realm.

LIMITATIONS AND FUTURE DIRECTIONS

Seemingly no body of population health research is complete without a call for better data, and this dissertation is of course no exception. Across each of the three studies, the primary limitation has been the availability of data sources that contain both biological and sociodemographic measures with large enough and diverse enough Hispanic samples to allow analyses to be fully stratified by key dimensions of interest to fully understand current patterns and to explore and prioritize possible areas of intervention. In designing this dissertation, I tried to be resourceful and as attentive to this concern as possible, bringing in seven major population data sources across the three studies to best answer the questions laid out for the project. However, along the way, compromises had to be made to preserve large enough sample sizes across subgroups to power analyses and detect meaningful patterns. In practice, this meant prioritizing stratification by immigration status and duration of residence in Paper 1, while sacrificing the ability to separately tease out patterns by sex. In Paper 2, this meant retaining full stratification by racial-ethnic group and nativity status yet facing the tradeoff of introducing more uncertainty into the final estimates and likely lacking the power to detect differential rates of obesity-related mortality risk across the six population groups of interest defined by sex, race-ethnicity, and nativity. In Paper 3, this similarly meant prioritizing the novel ability to create a cross-national dataset of older adults in both Mexico and the US yet lacking the sample size to power stratified models by sex and, again, being unable to detect differential mortality risk associated with metabolic syndrome and individual conditions for each racial-ethnic group by country of origin.

In sum, the common limitation across each paper that prevented me from probing deeper in my analyses, generating more tailored recommendations for intervention, or selecting more specific priority areas to direct policy change, all stem from a lack of large, representative data sources with a wide range of social and biological variables and robust and diverse samples of Hispanics by immigration or generational status, time spent in the US, and country of origin. Given this, it is largely data availability that will determine what paths are possible for the future direction of research on the shifting metabolic health and mortality patterns among the US Hispanic population. Based on the work presented here, a key priority moving forward will be to settle the question of whether US Hispanics—and, in particular, specific subgroups—face greater mortality risks from obesity and other metabolic health conditions, and if so, the extent to which these differences can be attributed to differences in the magnitude or severity of health conditions or to differences in the social determinants of healthcare and treatment. Better understanding these questions might update expectations about how vulnerable the Hispanic mortality advantage currently is and help to pinpoint specific segments of the Hispanic population and particular areas of social disadvantage that need to be resolved to address underlying disparities in social conditions that give rise to disparities in the patterning of health conditions and their consequences.

CONCLUSION

Returning to the question that prompted this work, will obesity and related metabolic conditions erode the overall Hispanic mortality advantage in coming decades? In a few words, no, probably not. However, what the body of research contained in this dissertation has shown is that a singular focus on this question alone masks other emergent patterns worthy of attention and response to prevent health disparities from emerging or widening and potentially changing the outlook to this question over a longer time-horizon. This dissertation project has revealed multiple areas of vulnerability facing key segments of the US Hispanic population, particularly the waning metabolic health advantage of recent Mexican immigrants to the US and older Mexican-origin populations who face great metabolic health burdens and heightened mortality risks driven by elevated blood glucose levels. Attending to these areas of concern, particularly as demographic processes already in motion continue to heighten the potential impact on the US population overall, will be essential tasks in the broader work of promoting the health and longevity of the entire US population in an equitable fashion.

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Appendices

Appendix A. Supplementary Material for Chapter 2

Table A-1. Race-ethnicity, country of origin, duration of residence disparities and the social determinants of metabolic syndrome (MetS)

	PRR	95% CI
Racial-ethnic/country of origin/duration of residence disparity (reference = US-born white)		
US-born Mexican American	1.24**	(1.10, 1.39)
Foreign-born Mexican, residing in US < 10 years	1.04	(0.85, 1.27)
Foreign-born Mexican, residing in US ≥ 10 years	1.13*	(1.01, 1.27)
Demographic characteristics		
Age	1.07***	(1.06, 1.08)
Age^2	0.9995***	(0.9994, 0.9996)
Gender (1 = male)	1.09**	(1.04, 1.15)
Socioeconomic characteristics		
Education (reference = less than high school)		
High school or GED	1.02	(0.94, 1.10)
Some college or college graduate	0.89**	(0.82, 0.96)
Income-to-poverty ratio (PIR)	0.96***	(0.94, 0.99)
Employment (reference = not employed)		
Part time (1-34 h/week)	0.89*	(0.82, 0.98)
Full time (≥ 35 h/week)	0.98	(0.92, 1.05)
Health behaviors		
Smoking, years spent	0.9996	(0.9981, 1.0010)
Alcohol (reference = never drinker)		
Former drinker	0.88***	(0.82, 0.94)
Current drinker	0.90**	(0.84, 0.96)
Food security (reference = full food security)		
Marginal food security	1.16**	(1.06, 1.27)
Low/very low food security	1.13**	(1.05, 1.22)
Time (reference = 1999-2000)		
2001-2002	1.07	(0.98, 1.17)
2003-2004	1.09	(0.97, 1.23)

2005-2006	1.03	(0.91, 1.16)
2007-2008	1.07	(0.96, 1.20)
2009-2010	1.08	(0.99, 1.18)
2011-2012	1.10	(0.98, 1.25)
2013-2014	1.12	(1.00, 1.25)
2015-2016	1.23**	(1.08, 1.39)
Interactions		
Gender x race-ethnicity/country of origin/duration of residence		
Male x US-born Mexican American	0.90	(0.80, 1.02)
Male x Foreign-born Mexican in US < 10 years	0.60**	(0.45, 0.81)
Male x Foreign-born Mexican in US ≥ 10 years	0.80**	(0.71, 0.92)
Education x race-ethnicity/country of origin/duration of residence		
High school or GED x US-born Mexican American	0.94	(0.80, 1.11)
High school or GED x Foreign-born Mexican in US < 10 years	0.98	(0.63, 1.53)
High school or GED x Foreign-born Mexican in US ≥ 10 years	0.78*	(0.63, 0.98)
Some college or college graduate x US-born Mexican American	1.09	(0.95, 1.24)
Some college or college graduate x Foreign-born Mexican in US < 10 years	0.76	(0.47, 1.25)
Some college or college graduate x Foreign-born Mexican in US ≥ 10 years	1.07	(0.86, 1.33)

Notes. Results based on Poisson regression model with log link function and robust standard errors. Prevalence rate ratios (PRR) and 95% confidence intervals (CIs) reported. *$P < .05$, **$P < .01$, ***$P < .001$.

Table A-2. Predicted prevalence rates of metabolic syndrome (MetS) associated with demographic, socioeconomic, and health behavior characteristics by race-ethnicity, country of origin, and duration of residence

	US-born				Foreign-born Mexicans (FBM)			
	Non-Hispanic whites (NHW) (*N* = 7,700)		Mexican Americans (MA) (*N* = 1,334)		In US < 10 years (*N* = 491)		In US 10+ years (*N* = 1,308)	
	PPR (%)[a]	95% CI	PPR (%)[a]	95% CI	PPR (%)[a]	95% CI	PPR (%)[a]	95% CI
Demographic characteristics								
Age								
20 years-old	17.4†§	(15.6, 19.5)	22.9*‡§	(20.5, 25.6)	16.1†§	(13.7, 18.8)	20.8*†‡	(18.4, 23.6)
35 years-old	33.2†§	(31.5, 34.9)	43.7*‡§	(41.2, 46.4)	30.6†§	(26.6, 35.1)	39.6*†‡	(36.5, 43.0)
50 years-old	50.7†§	(48.6, 52.8)	66.8*‡§	(62.7, 71.1)	46.7†§	(40.3, 54.1)	60.5*†‡	(55.6, 65.9)
65 years-old	62.1†§	(59.6, 64.7)	81.8*‡§	(76.0, 88.1)	57.2†§	(48.9, 67.0)	74.2*†‡	(67.6, 81.4)
80 years-old	61.0†§	(56.2, 66.4)	80.4*‡§	(71.9, 89.9)	56.3†§	(47.1, 67.3)	72.9*†‡	(64.3, 82.6)
Gender								
Female	45.5†	(43.4, 47.8)	58.3*‡§	(53.8, 63.2)	40.3†	(29.5, 55.0)	50.9†	(44.8, 57.9)
Male	49.7†‡	(47.3, 52.2)	57.3*‡§	(52.3, 62.8)	26.7*†§	(18.5, 38.6)	44.3†‡	(37.8, 51.9)
Socioeconomic factors								
Education								
Less than high school	51.1†‡	(47.4, 55.1)	59.4*‡§	(53.9, 65.4)	41.1*†§	(35.9, 47.1)	51.0†‡	(46.3, 56.3)
High school or GED	51.9§	(49.0, 54.9)	57.2§	(51.3, 63.8)	41.1	(27.5, 61.4)	41.4*†	(33.7, 50.8)
Some college or college graduate	45.1†‡	(42.8, 47.6)	57.6*‡	(53.1, 62.6)	28.2*†§	(17.6, 45.3)	49.2‡	(41.0, 59.1)
Income-to-poverty ratio								
1.30	51.2†‡§	(48.6, 54.1)	65.1*‡§	(61.1, 69.4)	43.1*†§	(37.3, 49.9)	56.7*†‡	(52.2, 61.7)
1.85	50.0†‡§	(47.7, 52.5)	63.5*‡§	(59.8, 67.5)	42.1*†§	(36.4, 48.6)	55.4*†‡	(50.9, 60.2)
3.00	47.5†‡§	(45.5, 49.5)	60.3*‡§	(56.8, 64.1)	40.0*†§	(34.6, 46.1)	52.6*†‡	(48.1, 57.5)
Employment								
Not employed	48.0†§	(44.9 51.2)	63.2*‡§	(58.8, 67.9)	44.2†§	(38.0, 51.5)	57.2*†‡	(52.0, 63.0)
Part time (1-34 h/week)	42.9†§	(39.6, 46.4)	56.5*‡§	(51.1, 62.5)	39.5†§	(33.6, 46.5)	51.2*†‡	(46.1, 56.8)
Full time (≥ 35 h/week)	47.2†§	(45.2, 49.3)	62.2*‡§	(58.4, 66.3)	43.5†§	(37.6, 50.4)	56.3*†‡	(51.6, 61.5)

Health behaviors								
Smoking								
0 years	47.0†§	(44.8, 49.4)	61.9*‡§	(58.1, 65.9)	43.2†§	(37.4, 50.0)	56.1*†‡	(51.5, 61.0)
15 years	46.7†§	(44.9, 48.6)	61.5*‡§	(58.0, 65.2)	43.0†§	(37.1, 49.7)	55.7*†‡	(51.2, 60.6)
30 years	46.4†§	(44.5, 48.5)	61.1*‡§	(57.4, 65.0)	42.7†§	(36.8, 49.6)	55.4*†‡	(50.6, 60.5)
Alcohol								
Never/former drinker	51.3†§	(48.6, 54.2)	67.3*‡§	(63.1, 71.8)	46.7†§	(40.5, 54.0)	60.2*†‡	(55.3, 65.6)
Moderate drinker	45.0†§	(42.6, 47.6)	59.1*‡§	(55.0, 63.4)	41.0†§	(35.2, 47.8)	52.9*†‡	(48.1, 58.1)
Binge drinker	46.0†§	(43.4, 48.7)	60.3*‡§	(56.1, 64.9)	41.9†§	(36.0, 48.7)	54.0*†‡	(49.2, 59.3)
Food security								
Full food security	45.9†§	(44.0, 48.0)	58.9*‡§	(55.3, 62.9)	40.1†§	(34.6, 46.6)	52.6*†‡	(48.1, 57.5)
Marginal food security	53.0†§	(48.3, 58.2)	68.0*‡§	(61.6, 75.2)	46.3†§	(39.5, 54.4)	60.7*†‡	(54.3, 67.9)
Low/very low food security	52.0†§	(48.2, 56.0)	66.7*‡§	(61.7, 72.0)	45.4†§	(39.0, 52.9)	59.5*†‡	(54.2, 65.4)

Notes. [a] Predicted prevalence rate (PPR) associated with each independent variable (holding age at the sample mean of 46.5 and all other covariates at their observed levels for each individual) by race-ethnicity/country of origin/duration of residence group. Predicted rates are based on an underlying Poisson regression model with a log link function and robust standard errors, used to directly estimate the prevalence rate ratio between groups.

Symbols indicate a statistically significant difference in the predicted prevalence at the $\alpha = 0.05$ level between the respective group in each column and US-born non-Hispanic whites (*), US-born Mexican Americans (†), foreign-born Mexicans in the US < 10 years (‡), and foreign-born Mexicans in the US 10 or more years (§).

Appendix B. Supplementary Material for Chapter 3

Table B-1. Comparison of baseline parameters for discrete hazards complementary log-log regression model predicting mortality as a function of obesity at baseline and age 25 with and without an interaction by racial-ethnic/nativity category

	Model with interaction				Model without interaction (final version)			
Covariates	Exp. coeffs	SE	*t*	P > *t*	Exp. coeffs	SE	*t*	P > *t*
Racial-ethnic/nativity group (reference group = US-born whites)								
US-born Hispanics	0.95	0.18	–0.28	0.778	0.97	0.17	–0.14	0.886
Foreign-born Hispanics	0.89	0.12	–0.88	0.383	0.96	0.14	–0.26	0.792
Sex, male	1.47	0.12	4.86	0.000	1.47	0.12	4.80	0.000
Age, years beyond 40	1.09	0.01	17.99	0.000	1.09	0.01	18.24	0.000
Current BMI (reference group = Normal/Overweight (18.5-29.9 kg/m^2)								
Obese I (30.0-34.9 kg/m^2)	1.94	0.73	1.76	0.082	2.05	0.76	1.95	0.054
Obese II-III (35.0+ kg/m^2)	3.12	1.02	3.48	0.001	3.10	0.97	3.62	0.000
Age-25 BMI (reference group = Normal/Overweight (18.5-29.9 kg/m^2)	1.22	0.22	1.08	0.284	1.22	0.22	1.09	0.279
Current BMI x racial-ethnic/nativity group								
Obese I x US-born Hispanics	1.09	0.33	0.27	0.786	–	–	–	–
Obese I x foreign-born Hispanic	1.42	0.52	0.95	0.343	–	–	–	–
Obese II x US-born Hispanics	1.04	0.49	0.09	0.928	–	–	–	–
Obese II x foreign-born Hispanics	0.90	0.25	–0.39	0.700	–	–	–	–
Education (reference group = less than high school)								
High school or GED	0.67	0.07	–3.61	0.000	0.67	0.07	–3.61	0.000
Some college or college graduate	0.58	0.06	–4.92	0.000	0.58	0.06	–4.92	0.000
Smoking status (reference group = never smoker)								
Former smoker	1.26	0.13	2.25	0.027	1.26	0.13	2.24	0.027
Current smoker	2.15	0.25	6.50	0.000	2.15	0.25	6.49	0.000
Year	0.85	0.01	–12.09	0.000	0.85	0.01	–12.11	0.000

Notes. Data are derived from pooled waves of NHANES III (1988–1994) and continuous NHANES (1999–2014) with mortality follow-up provided by linked National Death Index files through 2015. To reduce bias in our estimates of the mortality effects of obesity from reverse causation, we eliminate the first three years of exposure and also exclude individuals with emphysema or a smoking-related cancer at baseline. Exclusions are also made for respondents who were pregnant or underweight (BMI < 18.5 kg/m^2). Estimates reflect survey weights and complex survey design. Sample size = 20,554 subjects, representing 137,486.8 person-years at risk and 3,277 deaths.

Table B-2. Comparison of predicted and actual obesity distributions (95% confidence intervals (CI)) for males by age and racial-ethnic/nativity group, 2005 to 2015

		US-born whites			US-born Hispanics			Foreign-born Hispanics		
Age	BMI Category	Predicted Value	Actual (95% CI)		Predicted Value	Actual (95% CI)		Predicted Value	Actual (95% CI)	
35-54	Normal (18.5-24.9 kg/m^2)	0.20	0.16	(0.13, 0.20)	0.11	0.10	(0.06, 0.16)	0.14	0.14	(0.11, 0.19)
	Overweight (25.0-29.9 kg/m^2)	0.40	0.42	(0.37, 0.47)	0.35	0.36	(0.29, 0.44)	0.46	0.46	(0.40, 0.53)
	Obese I (30.0-34.9 kg/m^2)	0.25	0.28	(0.23, 0.32)	0.32	0.28	(0.20, 0.36)	0.28	0.29	(0.24, 0.35)
	Obese II-III (35.0+ kg/m^2)	0.15	0.14	(0.11, 0.18)	0.23	0.26	(0.17, 0.38)	0.12	0.10	(0.08, 0.14)
55-69	Normal (18.5-24.9 kg/m^2)	0.14	0.19	(0.15, 0.24)	0.13	0.10	(0.06, 0.15)	0.11	0.14	(0.10, 0.19)
	Overweight (25.0-29.9 kg/m^2)	0.39	0.39	(0.33, 0.46)	0.40	0.40	(0.26, 0.57)	0.47	0.50	(0.43, 0.57)
	Obese I (30.0-34.9 kg/m^2)	0.29	0.25	(0.20, 0.31)	0.31	0.32	(0.22, 0.44)	0.30	0.23	(0.18, 0.30)
	Obese II-III (35.0+ kg/m^2)	0.18	0.17	(0.12, 0.22)	0.16	0.18	(0.11, 0.29)	0.11	0.13	(0.09, 0.20)
70-84	Normal (18.5-24.9 kg/m^2)	0.12	0.17	(0.15, 0.20)	0.10	0.19	(0.13, 0.26)	0.14	0.28	(0.18, 0.42)
	Overweight (25.0-29.9 kg/m^2)	0.40	0.42	(0.39, 0.45)	0.36	0.40	(0.28, 0.54)	0.45	0.43	(0.29, 0.59)
	Obese I (30.0-34.9 kg/m^2)	0.30	0.27	(0.24, 0.30)	0.33	0.29	(0.19, 0.42)	0.29	0.19	(0.11, 0.32)
	Obese II-III (35.0+ kg/m^2)	0.18	0.14	(0.13, 0.16)	0.21	0.12	(0.08, 0.20)	0.12	0.09	(0.03, 0.24)
RMSE[a]		0.03			0.04			0.06		
Predictions that fall within 95% CI of actual values (%)		75%			83%			92%		

Notes. Data for the 2015 predicted values come from the following sources: Initial population counts are from continuous NHANES waves 2003-2006, data to differentiate life tables by BMI category come from NHANES III (1988-1994) and continuous NHANES waves 1999-2014 with mortality follow-up through 2015, data to differentiate Hispanic life tables by nativity come from NHIS 1989-2014 with mortality follow-up through 2015, data for transition matrices come from continuous NHANES waves 1999-2014. Data for the actual 2015 values come from continuous NHANES waves 2013-2016.

[a] RMSE is the root mean-squared error, used to assess error in predictions, calculated by comparing predicted to actual BMI values across age categories within each racial-ethnic/nativity group.

Table B-3. Comparison of predicted and actual obesity distributions (95% confidence intervals (CI)) for females by age and racial-ethnic/nativity group, 2005 to 2015

		US-born whites			US-born Hispanics			Foreign-born Hispanics		
Age	BMI Category	Predicted Value	Actual (95% CI)		Predicted Value	Actual (95% CI)		Predicted Value	Actual (95% CI)	
35-54	Normal (18.5-24.9 kg/m^2)	0.29	0.31	(0.26, 0.37)	0.11	0.14	(0.11, 0.19)	0.15	0.19	(0.15, 0.25)
	Overweight (25.0-29.9 kg/m^2)	0.27	0.27	(0.24, 0.31)	0.23	0.20	(0.14, 0.28)	0.32	0.33	(0.27, 0.39)
	Obese I (30.0-34.9 kg/m^2)	0.21	0.19	(0.16, 0.22)	0.26	0.25	(0.18, 0.34)	0.32	0.30	(0.25, 0.35)
	Obese II-III (35.0+ kg/m^2)	0.23	0.23	(0.19, 0.27)	0.41	0.41	(0.32, 0.49)	0.22	0.18	(0.15, 0.22)
55-69	Normal (18.5-24.9 kg/m^2)	0.21	0.24	(0.19, 0.29)	0.11	0.14	(0.08, 0.22)	0.16	0.15	(0.11, 0.21)
	Overweight (25.0-29.9 kg/m^2)	0.24	0.27	(0.21, 0.33)	0.22	0.29	(0.21, 0.38)	0.29	0.35	(0.29, 0.41)
	Obese I (30.0-34.9 kg/m^2)	0.24	0.26	(0.22, 0.30)	0.23	0.26	(0.19, 0.35)	0.30	0.25	(0.20, 0.31)
	Obese II-III (35.0+ kg/m^2)	0.30	0.24	(0.19, 0.29)	0.44	0.31	(0.21, 0.44)	0.25	0.24	(0.19, 0.30)
70-84	Normal (18.5-24.9 kg/m^2)	0.20	0.27	(0.23, 0.32)	0.11	0.13	(0.08, 0.22)	0.09	0.15	(0.09, 0.24)
	Overweight (25.0-29.9 kg/m^2)	0.26	0.37	(0.33, 0.41)	0.25	0.27	(0.18, 0.38)	0.30	0.38	(0.29, 0.49)
	Obese I (30.0-34.9 kg/m^2)	0.26	0.21	(0.17, 0.26)	0.28	0.37	(0.20, 0.58)	0.38	0.28	(0.18, 0.41)
	Obese II-III (35.0+ kg/m^2)	0.29	0.14	(0.10, 0.20)	0.37	0.24	(0.11, 0.44)	0.23	0.19	(0.11, 0.30)
RMSE		0.06			0.07			0.05		
Predictions that fall within 95% CI of actual values (%)		75%			100%			100%		

Notes. Data for the 2015 predicted values come from the following sources: Initial population counts are from continuous NHANES waves 2003-2006, data to differentiate life tables by BMI category come from NHANES III (1988-1994) and continuous NHANES waves 1999-2014 with mortality follow-up through 2015, data to differentiate Hispanic life tables by nativity come from NHIS 1989-2014 with mortality follow-up through 2015, data for transition matrices come from continuous NHANES waves 1999-2014. Data for the actual 2015 values come from continuous NHANES waves 2013-2016.

[a] RMSE is the root mean-squared error, used to assess error in predictions, calculated by comparing predicted to actual BMI values across age categories within each racial-ethnic/nativity group.

Appendix C. Supplementary Material for Chapter 4

Table C-1. Metabolic syndrome and mortality risk: Older adults in the Health and Retirement Study (HRS, 2006-2014) and the Mexican Health and Aging Study (MHAS, 2012) (*N* = 13,866)

	HR	95% CI
Metabolic syndrome	1.10	(0.96, 1.26)
Racial-ethnic/nativity/country of residence disparity (reference = US-born white)		
US-born Mexican American	1.31	(0.80, 2.15)
Mexican immigrant to US	0.66	(0.31, 1.38)
Mexican living in Mexico	0.86	(0.59, 1.25)
Age, centered at 50	1.03*	(1.01, 1.06)
Age^2	1.001***	(1.001, 1.002)
Year	1.02*	(1.00, 1.04)
Sex, male	1.34***	(1.17, 1.53)
Education (reference = less than upper secondary)		
Upper secondary/vocational	0.77**	(0.64, 0.92)
Tertiary	0.51***	(0.40, 0.64)
Smoking, years spent up to age 50 [mean (SE)]	1.02***	(1.02, 1.03)
Interactions		
Education x race-ethnicity/nativity/country of residence		
Upper secondary/vocational x US-born Mexican Americans	0.58	(0.27, 1.25)
Upper secondary/vocational x Mexican immigrant to US	0.45	(0.15, 1.33)
Upper secondary/vocational x Mexican living in Mexico	0.49	(0.06, 3.72)
Tertiary x US-born Mexican Americans	2.21	(0.64, 7.67)
Tertiary x Mexican immigrant to US	0.75	(0.19, 2.99)
Tertiary x Mexican living in Mexico	4.23**	(1.78, 10.04)

Notes. Results based on complementary log-log regression with exponentiated coefficients. Hazard ratios (HR) and 95% confidence intervals (CIs) reported. **P* < .05, ***P* < .01, ****P* < .001.

Table C-2. Obesity and mortality risk: Older adults in the Health and Retirement Study (HRS, 2006-2014) and the Mexican Health and Aging Study (MHAS, 2012) (*N* = 13,866)

	HR	95% CI
Obesity	0.97	(0.84, 1.13)
Racial-ethnic/nativity/country of residence disparity (reference = US-born white)		
US-born Mexican American	1.31	(0.80, 2.15)
Mexican immigrant to US	0.66	(0.32, 1.39)
Mexican living in Mexico	0.86	(0.59, 1.25)
Age, centered at 50	1.04*	(1.01, 1.06)
Age^2	1.001***	(1.001, 1.002)
Year	1.02*	(1.00, 1.04)
Sex, male	1.33***	(1.16, 1.52)
Education (reference = less than upper secondary)		
Upper secondary/vocational	0.77**	(0.64, 0.92)
Tertiary	0.50***	(0.40, 0.64)
Smoking, years spent up to age 50 [mean (SE)]	1.02***	(1.02, 1.03)
Interactions		
Education x race-ethnicity/nativity/country of residence		
Upper secondary/vocational x US-born Mexican Americans	0.58	(0.27, 1.26)
Upper secondary/vocational x Mexican immigrant to US	0.45	(0.15, 1.33)
Upper secondary/vocational x Mexican living in Mexico	0.51	(0.07, 3.86)
Tertiary x US-born Mexican Americans	2.25	(0.65, 7.81)
Tertiary x Mexican immigrant to US	0.75	(0.19, 2.97)
Tertiary x Mexican living in Mexico	4.28**	(1.80, 10.15)

Notes. Results based on complementary log-log regression with exponentiated coefficients. Hazard ratios (HR) and 95% confidence intervals (CIs) reported. **P* < .05, ***P* < .01, ****P* < .001.

Table C-3. High waist circumference and mortality risk: Older adults in the Health and Retirement Study (HRS, 2006-2014) and the Mexican Health and Aging Study (MHAS, 2012) (N = 13,866)

	HR	95% CI
High waist circumference	1.03	(0.90, 1.18)
Racial-ethnic/nativity/country of residence disparity (reference = US-born white)		
US-born Mexican American	1.32	(0.80, 2.15)
Mexican immigrant to US	0.66	(0.32, 1.39)
Mexican living in Mexico	0.87	(0.60, 1.27)
Age, centered at 50	1.03*	(1.01, 1.06)
Age^2	1.001***	(1.001, 1.002)
Year	1.02*	(1.00, 1.04)
Sex, male	1.33***	(1.17, 1.52)
Education (reference = less than upper secondary)		
Upper secondary/vocational	0.77**	(0.64, 0.92)
Tertiary	0.51***	(0.40, 0.64)
Smoking, years spent up to age 50 [mean (SE)]	1.02***	(1.02, 1.03)
Interactions		
Education x race-ethnicity/nativity/country of residence		
Upper secondary/vocational x US-born Mexican Americans	0.58	(0.27, 1.25)
Upper secondary/vocational x Mexican immigrant to US	0.45	(0.15, 1.34)
Upper secondary/vocational x Mexican living in Mexico	0.50	(0.07, 3.82)
Tertiary x US-born Mexican Americans	2.22	(0.64, 7.70)
Tertiary x Mexican immigrant to US	0.75	(0.19, 2.99)
Tertiary x Mexican living in Mexico	4.25**	(1.79, 10.09)

Notes. Results based on complementary log-log regression with exponentiated coefficients. Hazard ratios (HR) and 95% confidence intervals (CIs) reported. *$P < .05$, **$P < .01$, ***$P < .001$.

Table C-4. High blood pressure and mortality risk: Older adults in the Health and Retirement Study (HRS, 2006-2014) and the Mexican Health and Aging Study (MHAS, 2012) (*N* = 13,866)

	HR	95% CI
High blood pressure	0.96	(0.84, 1.09)
Racial-ethnic/nativity/country of residence disparity (reference = US-born white)		
US-born Mexican American	1.31	(0.80, 2.15)
Mexican immigrant to US	0.66	(0.31, 1.39)
Mexican living in Mexico	0.87	(0.60, 1.27)
Age, centered at 50	1.04**	(1.01, 1.06)
Age^2	1.001***	(1.001, 1.002)
Year	1.02*	(1.00, 1.04)
Sex, male	1.33***	(1.17, 1.52)
Education (reference = less than upper secondary)		
Upper secondary/vocational	0.77**	(0.64, 0.92)
Tertiary	0.50***	(0.40, 0.64)
Smoking, years spent up to age 50 [mean (SE)]	1.02***	(1.02, 1.03)
Interactions		
Education x race-ethnicity/nativity/country of residence		
Upper secondary/vocational x US-born Mexican Americans	0.58	(0.27, 1.26)
Upper secondary/vocational x Mexican immigrant to US	0.45	(0.15, 1.34)
Upper secondary/vocational x Mexican living in Mexico	0.50	(0.07, 3.83)
Tertiary x US-born Mexican Americans	2.24	(0.64, 7.76)
Tertiary x Mexican immigrant to US	0.75	(0.19, 2.98)
Tertiary x Mexican living in Mexico	4.28**	(1.80, 10.15)

Notes. Results based on complementary log-log regression with exponentiated coefficients. Hazard ratios (HR) and 95% confidence intervals (CIs) reported. $^*P < .05$, $^{**}P < .01$, $^{***}P < .001$.

Table C-5. Low high-density cholesterol and mortality risk: Older adults in the Health and Retirement Study (HRS, 2006-2014) and the Mexican Health and Aging Study (MHAS, 2012) (*N* = 13,866)

	HR	95% CI
High blood pressure	1.11	(0.97, 1.28)
Racial-ethnic/nativity/country of residence disparity (reference = US-born white)		
US-born Mexican American	1.32	(0.80, 2.16)
Mexican immigrant to US	0.66	(0.31, 1.39)
Mexican living in Mexico	0.84	(0.58, 1.23)
Age, centered at 50	1.03*	(1.01, 1.06)
Age^2	1.001***	(1.001, 1.002)
Year	1.02*	(1.00, 1.04)
Sex, male	1.34***	(1.18, 1.53)
Education (reference = less than upper secondary)		
Upper secondary/vocational	0.77**	(0.64, 0.93)
Tertiary	0.51***	(0.40, 0.65)
Smoking, years spent up to age 50 [mean (SE)]	1.02***	(1.02, 1.03)
Interactions		
Education x race-ethnicity/nativity/country of residence		
Upper secondary/vocational x US-born Mexican Americans	0.58	(0.27, 1.25)
Upper secondary/vocational x Mexican immigrant to US	0.44	(0.15, 1.32)
Upper secondary/vocational x Mexican living in Mexico	0.49	(0.06, 3.71)
Tertiary x US-born Mexican Americans	2.22	(0.64, 7.71)
Tertiary x Mexican immigrant to US	0.75	(0.19, 2.99)
Tertiary x Mexican living in Mexico	4.21**	(1.78, 9.98)

Notes. Results based on complementary log-log regression with exponentiated coefficients. Hazard ratios (HR) and 95% confidence intervals (CIs) reported. $^*P < .05$, $^{**}P < .01$, $^{***}P < .001$.