# INFLUENCES OF MATERNAL ACCULTURATION ON EARLY CHILDHOOD OBESITY RISK: FROM COUNTRIES TO CHROMOSOMES

BY

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DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Community Health
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2018

Urbana, Illinois

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## ABSTRACT

Prevalence of obesity has disproportionately increased among Mexican children living in the US and Mexico. In the US, by 2014, prevalence of obesity among children of Mexican heritage was similar for US-born and Mexican born children. In Mexico, from 1999 to 2006, obesity prevalence among children ages 5 to 11 years old increased by 40%.

Acculturation to the US culture has been linked to an 'immigrant health advantage' for foreign-born, and less acculturated Hispanic/ Latinos, and increases in obesity prevalence for the more acculturated counterparts. Modern forms of globalization have led to modern forms of communications facilitating the development of 'meaningful interpersonal interactions' which can also produce acculturation remotely. In lieu of the disproportionately high obesity increases among Mexican children in the US and Mexico, the objective of this dissertation is to investigate if currently, modern forms of acculturation influence obesity risks of young Mexican children living in the US and Mexico.

Using the socio-ecological framework of the Six-C's model and data from the Family-based Intergenerational Evaluation of Salivary Telomere-lengths and Acculturation (FIESTA!) study this dissertation examines the influence of maternal acculturation on early childhood obesity risks from three different perspectives. Recruitment for the FIESTA Study took place at a low-income Kindergarten in Central Mexico, and in Central Illinois. Mothers completed a questionnaire that examined their level of acculturation to the US, and Mexican cultures, as well as the family nutrition and physical activity habits, and socioeconomic characteristics. Measurements from fasting glucose, lipid profile, saliva bios, and bioelectrical impedance analyses were collected from mother-child dyads (n=113).

We identified 75% of mothers and 31% of children in our sample had overweight or obesity. The first study revealed that living in the US was associated with lower child body fat ($b = -1.49$, $p < 0.05$); and higher HDL-cholesterol ($b = 12.13$, $p < 0.05$). There was also a marginal interaction among children living in the US, suggesting that higher maternal acculturation to the Mexican culture was associated with higher child total cholesterol (p =0.07). The second study showed that among children and mothers with the lowest level of acculturation to the US, longer telomere lengths were associated with lower adiposity in weight. There were no intergenerational associations between mother's salivary telomere lengths and their children's adiposity and vice versa. In the last study, we identified different behaviors associated with both maternal acculturation to the US and Mexican culture, and childhood obesity risks. The association of family sleep routine with child fat mass and maternal acculturation to the US, and Mexican culture introduces a potential venue for intervention and obesity prevention. Other behaviors associated with child obesity risks included monitoring screen time, and promoting a healthy environment with opportunities for physical activity, and limited screen exposure for children.

Together, findings highlight the importance of using a socio-ecological framework to better understand the different factors influencing early childhood obesity risks, and suggest new venues for intervention.

## ACKNOWLEDGEMENTS

It took multiple villages.

I owe a great deal of gratitude to a lot of incredible people who supported me throughout this long journey. First and foremost, I would like to thank my family. Thanks to my mom and dad for giving me the resources and personal support I needed to achieve my goals. Thanks for making me of me a strong determined (or *terca*) woman, who knows anything is possible, even if it has not been done before. Especially to my dad, all those oysters and thought-provoking conversations, taught me to be analytical and introduce me to the socio-ecological perspective that drives my research today. Thanks to my siblings, Ivonne and Enriquito. You are the best cheerleaders! Thanks for believing in me, and for dealing with many difficult things on my behalf so I can pursue a doctoral degree in the US. To my extended family, the Aguayo, Huerta, and Aguirre families, largely to my Tía Rosa, mis primos Saldivar, los chicos Malacara, Adriana and Michelle, Tía Elva Rodriguez, Silvia and Robert, Tío Javier, Marilu, and all the family members who came through for me and for my sibling when we most needed you. Your love and support enables my resiliency, and my progress.

I would also like to thank the Markes family for letting me take over your kitchen with my binders. Thanks to Joie and Bob for helping me with excel formulas, Leslie and Paul, thanks for helping me improve my grammar, and for patiently reading my papers. Your support is greatly appreciated. There is the family you are born into, and the family you pick. I would not have been able to complete this milestone if I did not had the love and support of my girls. Special thanks to Marianna Kiselev, for being you, and for always having the right and honest words I needed to hear. Thanks to all my cheerleaders in Canada, Chicago, and Mexico. I know I was able to complete this degree because of the amazing women in life, thank you all for staying by my side in the good and the bad times, for keeping me in your group, even when I moved away, and for always making me feel like I have never left, especially during the hardest times. I am so lucky to have you in my life. Gracias amigas. I love you all very much.

I want to thank my advisor, Dr. Andiara Schwingel for sharing her personal and academic wisdom with me from the day I walked into her office looking for a research assistant position. Thank you for welcoming into the Aging and Diversity Lab (ADL) twice, and for always making me feel welcome, safe, and supported. You provided me a stimulating space where I was able to develop mentoring, leadership, and research skills I need to excel professionally. I will be forever grateful to you for being a personal, and professional role model for me. I am incredibly fortunate to have received your continued guidance, never-ending patience, cheers, sincere appreciation, hugs, and occasional wine, chicken lasagna, and Brazilian pastel. Thanks mainly for not giving up on me, and for believing that I will overcome the most difficult time in my life, even when many, including me sometimes doubted it. I will have never gotten this far without you.

I want to thank all the members of my Committee for their advice, support, and willingness to be uncomfortable with my yearning to combine cellular health with sociocultural factors in a dyadic approach. I appreciate your flexibility, time, and the enthusiasm with which you approach this learning experience. In particular, I would like to recognize Dr. Wiley and Dr. Teran for agreeing to mentor me and financially support my desire to investigate telomere lengths.

Many professors contributed to my development, and it will be nearly impossible to thank you all adequately. I hope you know that I am grateful you were part of my journey. I thank you for going above and beyond, for sharing your passion for research, for answering my emails, and for fostering my curiosity and creativity.

Big thanks to all my unofficial advisers. Helen Binns, Adolfo Ariza, Mita Goel, and Joe Feinglass, thanks for your support, your friendship, your advice, and for being an inspiration to me. Michelle

Cardel thanks for empowering me to overcome adversity with your genuine kindness, and your happy folder. I am forever your fan!

Thanks to Rosalba Hernandez and the Positive Emotion Laboratory. Thanks for letting me be part of your stimulating meetings, for introducing me to your incredible team, and for being a model of what a great academic should be. I only regret you did not came earlier into my life.

I also want to thank Dr. Sharon Donovan, and the I-TOPP Fellowship Committee for believing in me, and inviting me into the I-TOPP community. By allowing to become an I-TOPP fellow I was able to learn more than I could have dare to try about childhood obesity and academic development. Without the academic and financial support you secured for me, I doubt I would have been able to become the transdisciplinary researcher I am today. Thanks for the introduction to a transdisciplinary community who enrich my academic and personal life in many ways.

Special thanks to Donna Whitehill for her diligence, attention to detail, and kindness. Thanks for taking care of me in a personal and professional manner. The research reported in Chapters 2 to 4 was based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2011-67001-30101.

The guidance and support I received from my I-TOPP fellow-peers, especially Maria Pineros, Julia Kim, Natasha Cole, and Katie Robinson was instrumental to help me complete my academic, and professional training. I would also like to acknowledge the personal and academic contribution of current and former members of the ADL Lab. I will miss our stimulating discussions, the picnics, and my Chilean-language instructions. Especial thanks to the "*topisimas*" Patricia Galvez, and Marcela Vizcarra and all current and former ADL members: Julie Bobitt, Kelechi Ibe-Lamberts, Emerson Sebastiao, André Pereira dos Santos, Taylor Jansen, Mariha (with a ha!) Khan, Reynaldo De Leon, all visiting scholars and undergraduate ADLers who contributed to develop a highly

supportive, cooperative and successful work environment. It was a pleasure to be part of your team. I am eternally in debt with the many undergraduate students and ADLers who participated in data entry, laboratory analyses, and literature review tasks. Your enthusiasm is the reason I want to continue working in academia. It was truly an honor to have been your mentor. I am excited to see the wonderful things you will accomplish!

Rosalba Aguirre-Pereyra, gracias! Thanks for welcoming my ideas with such enthusiasm, and enabling my research studies. You are beautiful person, inside and outside, and a wonderful mother. Thanks for hosting me, for waking me up early, for encouraging me to look my best, for making me breakfast, for the coffees from the *Oxxo* that help me complete my data collection. Thanks for never saying no to my requests, and always finding a solution to all problems, even when the only solution was to pick up Yoyis and getting *micheladas y Modelos*. Yoyis, thanks for being the best partner in crime.

I want to thank all the mothers and children who participated in the HOPS and FIESTA! Studies. None of this would have been possible without your support to these projects. Special thanks to 'Yeni' Sarahi, who assisted with the data collection in Mexico. Yeni, muchas gracias.

Most of all, I want to thank my husband Kevin E. Markes for his patience, for listening to me when I wanted to talk about telomeres for the 83rd time, for reading my papers about the same thing over and over, for making me a better writer, a better English speaker, and a better human being. Thanks for loving me and for loving Bruno. You once mentioned you love that I wake up with a smile every day. I wake up with a smile every day because of you.

To everyone who in one way or another came into my village to help me grow:

thank you, obrigada, спасибо, gracias.

*Dedication*

This dissertation is dedicated to my father, Enrique Aguayo Salas, who provided a cognitively stimulating environment for me since the day I was born, challenged me to pursue my goals, and loved me unconditionally until the day he died…

Gracias papá

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# CHAPTER 1: Introduction

Obesity and diabetes disproportionally affect Latinos, particularly Mexicans who account for nearly two-thirds of the Latino population in the United States (US) [1]. Currently, both Mexico and the U.S. are at the top of the list of countries with the highest prevalence of overweight and obesity [2]. This growing problem spares no age group. Epidemiological studies have found that weight disparities and underlying causes related to obesity appear as early as Kindergarten ages and widen through childhood [3]. In the U.S., by the time children enter Kindergarten, nearly 15% of them have overweight or obesity with the highest prevalence already found among Latino children [3]. Nearly 33% of 2 to 5 year old Mexican-American children have overweight or obesity [4]. Similar rates are found in Mexico, where prevalence of overweight and obesity in children ages 5 to 10 increase by 40% between 1999 and 2006 [5]. Considering obesity is a major risk factor for type 2 diabetes, and Mexicans have a greater degree of impaired fasting glucose, we can expect alarming increases in diabetes rates and increases in premature incidence of type 2 diabetes on both countries, Mexico and the US [6, 7].

Apart from poor dietary habits, physical inactivity, and lifestyle factors, socio-cultural factors have been recognized in the etiology of obesity. In the US, among Mexican immigrant, obesity and cardiovascular disease risks increase substantially with higher acculturation to the US culture [8-10]. Paradoxically, in the US, immigrants who often have greater exposure to environmental adversity linked to immigration, including high levels of poverty, lower education, language barriers, marginalization, isolation, and other socioeconomic disadvantages, have better cardiovascular health, exhibit higher resilience, and have longer life-expectancy than their native-born, and more acculturated counterparts [8, 9]. The negative influence of acculturation on health is primarily evidenced in the high prevalence of overweight and obesity rates among Latino immigrants with greater acculturation compared to the foreign-born Latinos [11]. The "immigrant health advantage" described in the Hispanic/Latino Health Paradox, is lost as immigrants undergo acculturation and assimilation processes and integrate into the mainstream US culture [10, 12].

In recent years Mexico underwent dramatic changes in obesity prevalence, particularly among pediatric populations. Obesity prevalence increased by 40% between 1999 and 2006 among children ages 5 to 11 years old in Mexico [5]. In the US, the immigrant advantage previously documented among foreign-born young appears to have disappeared. A recent study demonstrated Mexican-born children aged 4 to 17 years living in the US experienced the sharpest increase in obesity prevalence [5]. This rapid increase resulted in similar obesity prevalence rates for Mexican US-born, and Mexican born children [5].

Given these findings, we suggest that the immigrant advantage of Mexican immigrant families is being challenged by remote venues of cultural exposure to the US culture. In great part because of globalization, the influence of acculturation is no longer limited to immigrant populations [13]. Currently, non-immigrant populations are exposed to the US culture via remote mechanisms, such as television programs, social-media, imported goods, transnational immigration, and tourism [13]. However, the influence of remote acculturation may be more salient for Mexico given its geographic condition, and the growing socio-economic relationships between both countries. These lead us to suggest that the current complex international context resulted in the increasing availability of the US culture to Mexicans living in Mexico and the US, and introduced obesity risks to young children with immigrant and non-immigrant Mexican parents. Furthermore, we hypothesize the health influence of acculturation begins at the end of the chromosomes, in the telomeres. Telomeres are protein caps sensitive to damage from environmental adversity [14]. We propose, the environmental stress introduced by acculturation will result in accelerated telomere shortening linked to increase adiposity, and increased obesity prevalence.

This dissertation focuses on three aspects of the influence of acculturation to early childhood obesity risks that are examined in three studies. Each one of the three studies included in this dissertation examines a different aspect of the influence of maternal acculturation to children's health. In the first study, we study the association between maternal acculturation and child health, and explore differences in the metabolic health of young children related to mothers' acculturation to the US and to mothers' acculturation to the Mexican culture. This study also explores the role of the different modes of cultural exposure, and differences between acculturation through immigration and remote acculturation. This is done by examining the moderating effect of country of residence in the relationship between acculturation with indicators of metabolic health in early childhood.

In the second study, we investigate the influence of maternal acculturation in the relationship between cellular health and obesity risks within the context of child-mother relationships. This study relies on an Actor-Partner interdependence statistical model to assess the direct, and the intergenerational influence of acculturation to the relationship between telomere lengths and adiposity in weight.

The third study focuses on the behavioral and environmental mechanisms through which maternal acculturation influences early childhood obesity risks. This study explores how acculturation influences 10 behavioral and environmental childhood obesity risk factors, and the corresponding health outcomes attributable to cultural influences. The influence of acculturation is examined in the context of bio-behavioral associations, with three biological outcomes: (1) telomere-lengths, (2) body-fat mass, and (3) age and sex appropriate body mass index percentile. The objective of this study is to identify specific behaviors that can inform strategies interested in limiting the negative influence of acculturation to childhood obesity.

All together, these studies will advance our understanding of the interplay of cultural, behavioral, and biological factors associated to increase risks of obesity and obesity-related disparities affecting children of Mexican heritage.

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# CHAPTER 2: Acculturation and metabolic health of young children of Mexican heritage living in Mexico and the US

## Introduction

Recent studies suggest that excessive weight gain during early childhood (i.e., under 5 years of age), is a more powerful indicator of adult fat and lean mass, than low birth weight [1]. However, findings regarding the long-term effects of childhood body composition (fat and lean mass) appear to be population-specific. In developing countries, early childhood weight gain is a predictor of height and lean mass in adults [2]. In contrast, body mass index (BMI) gains during early childhood, predicts fat mass (or obesity) in adults from industrialized countries [2]. These contradictory findings in growth pathways introduce a health challenge to countries and populations experiencing an accelerated nutritional transition from developing to industrialized economies. Among US Mexican immigrant populations, the rapid transition to an industrialized economy introduces an array of cultural and behavioral lifestyle demands that often result in energy imbalances, and higher obesity prevalence. This complex process by which immigrants gradually exchange the attitudes and behaviors from their heritage culture, and adopt those of the host culture is known as acculturation [3]. Increases in BMI and cardiovascular disease (CVD) risk factors with higher levels of acculturation to the US (industrialized) culture are well established among immigrant adults [3]. However, because most studies have focused on BMI assessments, less is known about the influence of acculturation or lack thereof on the relative proportions of fat and lean mass in weight, and their respective associations with metabolic health indicators during early childhood.

In the US, differences in growth trajectories, and disparities in obesity prevalence among immigrant populations have been explained by studying acculturation to the US culture. Studies have shown that spending more than 10 years in the US, and immigrating at a younger age is associated with higher vulnerability to obesity, and CVD among Mexican immigrant adults via higher acculturation to the US culture [4, 5]. Hispanic/Latinos with less acculturation to the US culture exhibit a health advantage in mortality linked to CVD, renal disease, and similar health conditions [3, 6]. Despite the plethora of studies examining the influence of acculturation on obesity and obesity related diseases, and the well-established importance of early life in the development of obesity [7, 8], studies examining the associations of acculturation to US culture with children health outcomes during early childhood are scarce. A systematic review examining the relationship between acculturation and obesity in childhood concluded that because of the dearth of research, the influence of acculturation to the US culture on child health outcomes is uncertain and may vary across the age-spectrum [8]. During early childhood, among children of Mexican-born mothers, lower maternal acculturation to the US is associated with lower child weight [9]. By elementary school age, the association between parental acculturation and obesity risks becomes ambiguous [8, 10, 11]. In adolescence, a significantly higher obesity risk was documented with higher acculturation to the US in the second and third immigration generations [8]. Differences in the directionality of the relationship during elementary school age may be associated with increasing divergence between child and parent acculturation processes, and the emergence of intergenerational acculturation gaps [12].

Currently, technological advances and globalization-driven cultural encounters and exchanges, have expanded the process of acculturation to include cultural interactions of immigrant and nonimmigrant populations, such as remote acculturation, and remote enculturation.

Nonimmigrants undergo *remote acculturation* through their exposure to a different culture by indirect and/or irregular contact with television programs, social-media, imported goods, tourists, and transnational immigrants [13]. Among immigrant families, nonimmigrant children (and sometimes adolescents or adults) experience r*emote enculturation* with their heritage culture through their family's intentional transmission of cultural practices, family efforts to socialize children ethnically/racially, socialization with cultural social networks living in the heritage country, and even from a distance through exposure to the culture via technology-mediated communications [14]. Studies of modern forms of cultural transmission processes suggest that the health implications previously documented in studies of acculturation now extend beyond immigrant populations. Similar health risks have been linked to novel forms of cultural interactions such as remote acculturation and/or enculturation [13, 14]. Among nonimmigrant Jamaican adolescents who have never lived in or visited the US, a higher American identity and behavioral preference was associated with higher intake of unhealthy foods, and increased risk for obesity [15]. In a study of Mexican-born and US-born Mexican adults living in the US, US-born, Spanish-speaking Mexican men and women had higher prevalence of abdominal obesity than their foreign-born, English speaking, less enculturated counterparts [16].

Obesity is a global public health concern. To limit the prevalence of obesity, it is necessary to better understand the relationship between the parallel increases in cultural exchanges and the prevalence of obesity and obesity-related diseases worldwide. Considering mothers have the greatest influence in the development of health behaviors in early childhood [17], it is imperative to begin by examining the influence of cultural determinants of obesity during the early childhood period. Studies of genetic and environmental factors that influence children's body composition, suggest mothers have a stronger influence on young children's growth, and excessive adiposity patterns than fathers [17]. The relative contribution of maternal cultural influences to early childhood obesity risks, and metabolic health has not been identified.

Utilizing precise measurements of body composition, we analyze the associations of maternal acculturation to the Mexican and US cultures, with their respective child's fat mass, lean mass and metabolic indicators of CVD risk. In order to contribute to moving the field of health disparities forward, the objective of this paper is to examine the influence of different modern forms of maternal acculturation on early childhood health outcomes. This will be done by analyzing the specific contributions from maternal acculturation (a) to the US culture, (b) to the Mexican culture, and (c) the moderation effect of country on the influence of maternal acculturation to both, the US and the Mexican cultures separately. We hypothesize that the associations of maternal acculturation to the US and Mexican cultures with children's health outcomes will be moderated by their country of residence, which modifies their form of exposure to each culture. Consistent with the aforementioned previous studies that examined the effects of acculturation on Hispanic health, children of Mexican heritage living in the US, are expected to have increased health risks.

## Subjects and Methods

### Procedures and participants

This cross-sectional study included 101 children ages 4 to 6 years old born to Mexican mothers living in San Luis Potosi, Mexico (n=78), and central Illinois (n=23) US, and their mothers. Children-mother dyads were recruited from a low-income Kindergarten in the outskirts of San Luis Potosi, Mexico. In central Illinois, recruitment was done using flyers, referrals from community leaders, and snowball sampling methods. Data was collected in participant's preferred language (Spanish or English). Mother and child height, body composition, blood glucose and lipid profile was measured after consent and parental consent was obtained. Mothers were also asked to complete a paper questionnaire that included assessments of their level of acculturation to the US and Mexican cultures, a questionnaire of family nutrition, and physical activity habits, and demographic information for child, mother and family. The research protocol was approved by the Institutional Review Board of the University of Illinois in Urbana-Champaign, and by the school principal of the Jorge Ferretis Kindergarten, and the Secretary General of Education of the State (*Secretaría de Educación de Gobierno del Estado, SEGE*) in San Luis Potosi, Mexico.

**Health outcome measures**

*Fat mass, truncal fat, and lean mass.* Body composition measurements were collected in light clothing and without shoes after overnight fasting. Fat mass, truncal fat, and lean mass measurements were collected from child and mother using an 8-point bioelectrical impedance analyzer (BIA) (InBody 230, Biospace Co., Ltd, Seoul, Korea).

***Blood glucose and lipid profile.*** Child blood glucose and lipid profile was measured after an 8-hour fasting from whole blood samples obtained from the child's fingertip. Child blood glucose was measured using a standard glucometer (Contour™, Bayer HealthCare LLC., Mishawaka, US). Lipid profile including total cholesterol, high density lipoprotein cholesterol (HDL-cholesterol), low density lipoprotein cholesterol (LDL-cholesterol), and triglycerides was measured using the CardioChek® PA Test System (CardioChek® PA, Polymer Technology Systems Inc., Indianapolis, US).

**Independent variables**

*Maternal acculturation to the US culture (MA-US), and maternal acculturation to the Mexican culture (MA-MX).* This study was based upon the understanding that the adoption of a new cultural practice does not compel relinquishment of a previous cultural practice, but may involve the sporadic implementation of both practices. Thus, the process of maternal acculturation was operationalized as a bidimensional construct: 1) Anglo oriented and, 2) Mexican oriented [18]. Both acculturation dimensions, MA-US and MA-MX were examined by relying upon the bidimensional properties of the Acculturation rating scale for Mexican Americans-II (ARSMA-II) [19]. This scale examines three factors (language preferences, ethnic identity, and ethnic interactions) in a continuum to determine the degree of orientation and engagement with the Mexican or the American cultures [19]. Outcomes from this scale include two conceptual meaningful factors: (1) MA-US, and (2) MA-MX.

Although the scale 1 of the ARSMA-II has been widely used to examine the influence of acculturation on health outcomes, some scholars are highly critical of this *imperfect* measurement [20]. Scholars argue that the three factors of acculturation examined by the ARSMA-II overlooked the adoption of unhealthy behaviors, and fail to account for the contributions to physical and mental health introduced by socioeconomic disadvantage, and chronic psychosocial stressors in a 'support limited environment' [20, 21]. Changes in behavioral factors (i.e. diet and physical activity), and psychosocial stressors have been associated with both the acculturation process and physical and mental health risks [20, 21]. To address this scale shortfall, items examining behavioral and cultural changes included in the subscale 2 of ARSMA-II were added to complement subscale 1, and factorial analysis was conducted to examine the explanatory value of the revised scale in our study sample. Following general guidelines, only items with significant correlations of .30 or greater with at least one other item, were included in the factor analyses. The Kaiser-Meyer-Olkin test (KMO) and the Bartlett's test of sphericity were used to examine the fit of the variables and the sample adequacy [22]. Results from exploratory factor analyses of the MA-US and MA-MX measures ensured acceptable construct validity and measurement in the study sample. Both the MA-US and the MA-MX subscales were found to have good internal reliabilities (Cronbach's Alpha = .92 and .88 for the MA-US and the MA-MX respectively). Following original scoring guidelines, the ARSMA-II, the mean MA-US score and MA-MX scores were calculated [19]. Outcomes from both subscales MA-US, and MA-MX were included in our analyses as continuous variables ranging from 1 to 5. Higher numbers indicate higher acculturation to either culture.

**Control variables**

*Children's gender and age, and maternal years of education completed.* Mothers were asked to report their child's gender and age, and the years of education they have completed in the semi-structured paper questionnaire. Child gender was included as a dichotomous categorical variable, and age and maternal years of education completed were entered as continuous variables.

*Sex specific height-for-age percentile.* Child height was measured to the nearest millimeter with a portable stadiometer (Seca 213, Seca Weighing and Measuring Systems, Hamburg, Germany). Sex specific height-for-age percentile was calculated using CDC standard growth curves [23]. Studies have shown that independent of adiposity, taller and faster growing children have elevated insulin resistance, and lower leptin values [2]. Considering these associations, it was decided to control for the effect of height-for-age percentile in all statistical analyses.

*Family Nutrition and Physical Activity (FNPA) Screening Tool.* The FNPA is a comprehensive validated scale developed by the USDA in partnership with the American Dietetics Association to examine parenting behaviors and family environments linked to increased risks for obesity in childhood [24]. The instrument examines ten behavioral factors linked to childhood obesity [24]. The scale can be interpret using an aggregate outcome, or examining each construct separately [24]. In this study, we use the aggregated outcome to separate the effect of maternal acculturation to the US and Mexican cultures, from the effect of health behaviors known to influence obesity risks (i.e. beverage choices, physical activity, screen time, etc.). The composite application of the scale had good internal reliability in this sample (Cronbach's Alpha = 0.63).

**Analytical models**

Exploratory factor analyses were initially conducted to assess the acculturation instrument (ARSMA-II) in the sample of Mexican women. In addition, the internal reliabilities of the ARSMA-II subscales, the FNPA, were examined to confirm reliability in respective constructs examined. Upon confirming the scale measures ensured acceptable construct validity and measurement in the study sample, measures of MA-US, MA-MX, and FNPA were used in all statistical analyses.

Demographic characteristics, anthropometric measurements, and health outcomes between the subsample from Mexico and the US were compared using chi-square tests for categorical data, and independent sample t-test, with the corresponding Levene's tests for continuous variables. Results for the t-tests were reported according to homogeneity of variances.

Main effects and interactions were examined upon confirming multicollinearity requirements. The variance inflation factor (VIF), with VIF> 2.5 with the criterion for multicollinearity suggested by Allison was used to examine all variables in the regression models [25]. All multiple linear regression models were used following the enter method to test the main effects and interactions of MA-US and MA-MX with different child body composition and metabolic health outcomes in three models. Child body composition measurements were examined first (1) body fat, (2) truncal fat, and (3) lean mass. These models are followed by the examination of metabolic health outcomes (4) fasting blood glucose, (5) total cholesterol, (6) HDL-cholesterol, (7) LDL-cholesterol, and (8) triglycerides. Control variables were first tested in block 1 to examine their contribution to each outcome tested. Country of residence (US or Mexico), and MA-US and MA-MX were included in block 2 to examine the main effects on the different child health outcomes. Lastly, the interaction terms were added in block 3. This last block examines the interaction of MA-US with country of residence (Tables 2.1 to 2.16); separately from the interaction between MA-MX with country of residence (Tables 2.2 to 2.17). The statistical models from tables 2.7 to 2.17 examining child metabolic outcomes included the same predictors and follow the same order described for tests of the body composition measurements. All models controlled for child gender, age, sex-specific height-for-age percentile, mother years of education completed, and family nutrition and physical activity in block 1. Descriptive and regression analyses were conducted in IBM SPSS version 24 (Statistical Package for the Social Sciences, version 24.0, SPSS Inc, Chicago, IL, US). Consecutive analyses of the simple slopes for interaction items were conducted in R Rweb1.03 (The R Foundation for Statistical Computing, RC Team 2013, Vienna, Austria) [26].

## Results

### Participant characteristics

The characteristics of the study participants are shown in Table 2.1. The total sample included 101 child-mother dyads recruited in Mexico (n =78 dyads), and in the US (n =23). Overall, 49.50% of children were male, and 33.90% of children had overweight or obesity. Sex-specific BMI-for-age percentile and prevalence of overweight and obesity was not significantly different between children in Mexico and the US. Of the children with overweight or obesity, 32.00% were recruited in Mexico, and 26.10% in the US. Children recruited in the US were significantly older (age in the US was 5.09 ±0.73 years, compared to 4.68 ±0.61 in Mexico; $p < 0.05$). Compared to children in Mexico, children in the US also had significantly higher lean body mass ($p < 0.05$), truncal fat (p

<0.05), blood glucose (p <0.05), and HDL cholesterol values (p <0.001). As expected, MA-MX was significantly higher among Mexican mothers living in Mexico (p <0.001), and MA-US was higher among Mexican mothers living in the US (p <0.001).

### Multiple linear regression models

The highest VIF was found among the sex-specific height for age percentile and country of residence (VIF= 2.21). These collinearity diagnostic analysis showed that multicollinearity among predictors, was unlikely to influence the results from the regression analyses.

Tables 2.2 to 2.17 show the results of the multiple regressions examining the influence of MA-US and MA-MX on child health outcomes. None of the health outcomes in the final models were associated to the composite measurements of family nutrition and physical activity habits (p >0.05).

### Assessments of body composition

Living in the US was associated with lower child body fat (b =-1.49, p <0.05) in the model examining the influence of acculturation to the US (Table 2.2). There was no statistically significant association with country of residence in the model examining the influence of acculturation to the Mexican culture (Table 2.3). Results from the different body composition measurements showed higher MA-US was not associated with higher child body fat, child truncal fat, or lean mass (p >0.05). Similarly, higher MA-MX was not associated with child body fat, child truncal fat, or lean mass (p >0.05). Country of residence was not associated with any other measurement of body composition.

### Assessments of metabolic health

Living in the US was associated with higher HDL-cholesterol (b =12.13, p <0.05). The moderation analyses showed a significant two-way interaction between MA-MX, and country of residence, on child total cholesterol (b=36.06, p <0.05). Simple slopes revealed that the positive association of MA-MX with child total cholesterol was only marginally significant among children living in the US (b =0.29.41, SE =15.87, t =1.85, p =0.07, but not among children living in Mexico (b=-6.65, SE=8.00, t=-0.83, p=0.41). This interaction is visually presented in Figure 2.1. No other interactions were significant.

The statistical models (Tables 2.8 to 2.17) showed no significant influence of the interactions between MA-US and country of residence, and the interaction MA-MX and country of residence. This means that the association of country of residence with fat mass in the MA-US model; and the association with HDL-cholesterol in the MA-MX model were independent of maternal acculturation to either the Mexican or the US cultures.

**Discussion**

Study findings suggest that living in the US introduces a protective effect to young Mexican children's health, which is independent of maternal acculturation to the US but not to the Mexican culture. Living in the US was associated with lower fat mass, and higher HDL-cholesterol in children. In contrast, greater acculturation to Mexico was associated with less optimal total cholesterol in children living in the US, and acculturation to the Mexican culture had no effect for children living in Mexico. Findings from the interaction between maternal acculturation to the Mexican culture with country of residence showed that, compared to their non-immigrant counterparts, young children of Mexican heritage living in the US are more vulnerable to hyperlipidemia.

We hypothesized children of Mexican heritage living in the US will be at increased health risks. This hypothesis was partially confirmed. However, contrary to what was expected higher acculturation to the Mexican culture introduced health risks. In contrasts, higher maternal acculturation to the US had no influence on children's overall body composition or metabolic health.

Higher acculturation to the US has been associated with higher intake of sugar and sugar sweetened beverages [27]. However, in our study we found no positive associations between maternal acculturation to the US with children's blood glucose or adiposity. Our lack of associations may be explained by recent changes to the dietary patterns resulting from obesity prevention efforts in the US. It is also possible that the lack of differences in blood glucose, and adiposity observed with greater acculturation to the US, and with both, maternal acculturation to the US and residence in the US may be due to the young age of children in our sample. Previous studies have documented differences in blood glucose, and adiposity are associated with child age and growth [2]. Thus, children may be too young to evidence country differences linked to acculturation and mode of exposure to the US and Mexican cultures. In a study of 7 to 12 year old boys and girls, Wells and Cole (2014) found increases in adiposity, lean mass, and height were independently associated with insulin resistance [2]. These findings lead the authors to suggest that insulin resistance could be a marker of growth along with adiposity [2]. The strong associations we found between child height-for-age percentile measurements with all child measurements of body composition and fasting glucose are consistent with these associations Wells and Cole (2014) found among older children [2].

Independent of maternal acculturation, living in Mexico was associated with lower HDL-cholesterol for children. These metabolic differences may be explained by current dietary and physical activity patterns associated with the Mexican culture. In 2010, a study of the dietary intake of children living in Mexico found that high-fat foods were the highest dietary energy sources of

9-13 year old children [28]. Perichart-Perera and colleges observed that of 228 children in Mexico, 90% had low HDL- cholesterol (<40 mg/dL), and 41% of children had higher triglycerides (≥150 mg/dL) [28]. Authors also found that lower intake of high-fat-dairy was associated with lower HDL-cholesterol, while higher intake of butter, cream, lard, and creamy dressing and sauces was associated with higher triglycerides [28]. In our study, dietary intake was not examined, yet given the similarities observed in the lipid profile of 9-13 year old children living in Mexico City, and the 4-6 year old children in our sample, it can be speculated that children have similar dietary patterns.

National studies have shown that Hispanic/Latinos are the most physically inactive minority in the US [29]. Although the association between physical activity and maternal acculturation to the Mexican culture was not examined, physical inactivity may explain the association we found between living in Mexico with fat mass, and HDL-cholesterol. Results from a systematic review of metabolic health indicators associated with physical activity, found that higher levels of physical activity are associated with better metabolic status in preschool age children [30]. Among 4 to 7 year old children from Finland, higher physical activity was associated with reductions in triglyceride levels among boys, and improvement in the HDL/total cholesterol among girls [31]. Future studies should examine the associations between intake of high-fat-foods and high inactivity in pediatric samples. Clinicians and researchers should assess if improvements in the body composition and lipid profile of young children of Mexican heritage can be achieved by limiting children's intake of added fats, and increasing their opportunities for physical activity.

The lack of an interaction between acculturation to the US with country of residence showed that in our sample, higher maternal acculturation to the US independent of country of residence, was not linked with children obesity and cardiovascular health risks. Increasing temporary and permanent migration movements, technological advances and globalization-driven cultural exchanges, have expanded the influence of acculturation to include nonimmigrant interactions. Future studies should examine the influence of maternal acculturation to the Mexican culture with Mexican immigrant populations around the world.

To our knowledge, this is the first study to examine the influence of maternal acculturation with precise measurements of body composition and metabolic health in a sample of young children with mothers exposed to different forms of cultural socialization with the US and Mexican cultures. In the limited number of studies assessing the nutritional status of immigrant children, BMI is the most widely used index of nutritional status. Although BMI indexes have several advantages such as affordability, and ease of use in clinical and non-clinical settings, because BMI indexes rely on height and growth, it is not possible to disentangle the differences in adiposity and lean mass [2]. This study adds to the literature by analyzing the contribution of maternal acculturation (from immigration or through remote acculturation) to early-life measurements of body composition and markers of cardiovascular disease risks among Mexican children. Another unique feature of this international study is the inclusion of two semi-urban environments in Mexico and the US, which may provide different insights on acculturation processes for less studied populations. Previous studies of acculturation among Mexican samples have mostly focused on adults living near the US/Mexico border or included populations from urban centers where Hispanic/Latino enclaves have developed [5, 32, 33]. Ethnic enclaves offer opportunities for traditional and remote enculturation to immigrants [14]. In contrast, children and mothers in our sample recruited from rural and semi-urban areas in Central Illinois depend heavily upon remote avenues of acculturation and their families for the cultural transmission of norms and values.

Ferguson et al., (2016) suggest remote enculturation fosters well-being among children of immigrants because it fortifies cultural identity, and family interactions [14]. However, in our sample, higher maternal acculturation to the heritage culture (Mexican) in children living in the US was associated with less optimal metabolic profile. In addition, living in Mexico was associated higher fat mass and lower HDL-cholesterol in children. These findings contradict the conjecture that a stronger cultural identity leads to better health outcomes. In light of the record high prevalence of obesity among children and adults living in Mexico, and given our study results, future studies should employ precise measurements of body composition to further examine traditional behaviors and their association, or lack thereof, with increased obesity and CVD risks.

**Limitations**

Findings should be considered with caution. This study relied upon a cross-sectional assessment of a non-randomized sample of child-mother dyads. This research methodology introduces important limitations. Study findings are not generalizable beyond the study sample. Results identified interactions between maternal acculturation processes, and child health outcomes. However, the biological mechanisms through which maternal acculturation –experienced through immigration, or remotely, influence young children's growth trajectories and cardiovascular health remain poorly understood. In addition, given our sample size, and the imbalanced between children subsamples, the interactions found lack sufficient statistical power. There are two key implications linked to our sample size. First, it is possible that maternal acculturation has an effect on child health that we were not able to identify, possibly because of the study's sample size. On the other hand, it is possible that the interaction with total cholesterol by country we identified for children living in the US, resulted from sample bias, and uneven distribution. Future studies should consider examining these associations with larger longitudinal cohorts that include multiple assessments of acculturation with mothers', and child measurements of body composition and cardiovascular health. Examinations starting at birth are recommended to provide information about the progression of the effects from maternal acculturation, and their relationship with the etiology of obesity and cardiovascular disease disparities.

**Conclusion**

It has been presumed that the lifestyle demands introduced by the US culture foster the development of environments that promote high energy intake and sedentary behaviors, resulting in higher prevalence of obesity and adverse metabolic health profiles [34]. Correspondingly, traditional lifestyles are associated with healthier metabolic outcomes. The results of this study indicate that higher acculturation to the US had no effect in the children's health, while higher acculturation to the Mexican culture among Mexican mothers living in the US was association with less optimal metabolic health in young children. In addition, living in Mexico was associated with higher fat mass, and a less favorable lipid profile in young children, independent of mother's acculturation. These findings, indicate that understanding the influences of cultural changes, and the impact from health and social policies is key to adequately adjust the design of prevention strategies to current challenges if we aim to reduce obesity and cardiovascular disease risks among Mexican children.

**Tables and Figure**

**Table 2.1.** Clinical and social characteristics of all study participants, and the Mexico and US child-mother dyads subgroups

| | All (n=101) %, (n)/ *m* ±sd | Mexico (n=78) %, (n)/ *m* ±sd | US (n=23) %, (n)/ *m* ±sd |
|---|---|---|---|
| **Children characteristics** | | | |
| Children's age* | 4.77 ±0.66 | 4.68 ±0.61 | 5.09 ±0.73 |
| 4 years old | 35.60 (36) | 39.70 (31) | 21.70 (5) |
| 5 years old | 51.50 (52) | 52.60 (41) | 47.80 (11) |
| 6 years old | 12.90 (13) | 7.70 (6) | 53.80 (7) |
| Gender (male)* | 49.50 (50) | 47.44 (37) | 56.52 (13) |
| Sex-specific height-for-age percentile | 49.26 ±32.69 | 49.70 ±33.40 | 47.75 ±30.83 |
| Sex-specific BMI-for-age percentile | 62.25 ±30.55 | 60.65 ±24.06 | 67.67 ±24.06 |
| Weight status$^{+}$ | | | |
| Underweight (<5$^{th}$ percentile) | 5.00 (5) | 6.40 (5) | - |
| Normal (5$^{th}$ to 84.9$^{th}$ percentile) | 64.40 (65) | 61.50 (48) | 73.90 (17) |
| Overweight (85$^{th}$ to 94.9$^{th}$ percentile) | 13.90 (14) | 12.80 (10) | 17.40 (4) |
| Obesity (>95$^{th}$ percentile) | 16.80 (17) | 19.20 (15) | 8.7 (2) |
| Fat mass (kg) | 5.28 ±2.56 | 5.37 ±2.63 | 4.97 ±2.34 |
| Lean body mass (kg)* | 6.10 ±1.66 | 5.90 ±1.51 | 6.77 ±1.99 |
| Truncal fat (kg)* | 5.39 ±1.69 | 5.20 ±1.65 | 6.07 ±1.69 |
| Blood glucose (mg/dL)* | 81.05 ±11.04 | 79.83 ±11.25 | 85.95 ±8.80 |
| Total cholesterol (mg/dL) | 139.00 ±30.49 | 136.89 ±20.79 | 147 ±53.46 |
| HDL cholesterol (mg/dL)** | 43.04 ±10.60 | 40.91 ±8.48 | 51.15 ±13.79 |
| LDL cholesterol (mg/dL) | 80.20 ±29.33 | 80.25 ±16.34 | 80.00 ±57.01 |
| Triglycerides (mg/dL) | 89.72 ±43.41 | 89.05 ±42.56 | 92.25 ±47.58 |
| **Mother characteristics** | | | |
| Mother's age (range 19 -55) | 30.33 ±7.00 | 29.73 ±7.17 | 32.48 ±6.02 |
| Mother's BMI | 27.64 ±4.52 | 27.15 ±4.23 | 29.58 ±5.23 |
| Maternal acculturation to Mexican culture*$^{++}$ | 4.59 ±0.61 | 4.69 ±0.46 | 4.27 ±0.89 |
| Maternal acculturation to US culture**$^{++}$ | 1.79 ±0.89 | 1.51 ±0.60 | 2.72 ±1.07 |
| Mother's mean years of education | 9.56 ±3.24 | 9.70 ±3.30 | 9.10 ±3.08 |
| USDA Family Nutrition and Physical Activity survey tool (FNPA)* | 2.80 ±0.42 | 2.77 ±0.41 | 2.89 ±0.47 |

*p ≤0.05; **p ≤0.01

$^{+}$CDC growth curve criteria

$^{++}$p-value equal variances not assume

**Table 2.2.** Regression coefficients of the associations between maternal acculturation to the US culture with children's measurements of body fat

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.28$ | | | | | |
| 1 | Sex (ref. male) | 0.61 | (-0.28, 1.51) | 0.41 | (-0.50, 1.32) | 0.38 | (-0.53, 1.30) |
| | Age | 1.02* | (0.33, 1.72) | 1.25** | (0.51, 1.99) | 1.21* | (0.47, 1.96) |
| | Sex-specific height-for-age percentile | 0.03** | (0.02, 0.05) | 0.03** | (0.02, 0.05) | 0.03** | (0.02, 0.05) |
| | Mother's years of education completed | 0.01 | (-0.13, 0.15) | -0.02 | (-0.17, 0.12) | -0.02 | (-0.17, 0.13) |
| | Family Nutrition and Physical Activity (FNPA) | 0.04 | (-0.02, 0.09) | 0.05 | (-0.01, 0.10) | 0.05 | (-0.01, 0.10) |
| | | | | $R^2 = 0.31$ | | | |
| 2a | Maternal acculturation to the US | | | 0.40 | (-0.26, 1.06) | 0.06 | (-0.84, 0.97) |
| | Country of residence (ref. Mexico) | | | -1.49* | (-2.95, -0.03) | -2.91 | (-5.88, 0.06) |
| | | | | | | $R^2 = 0.32$ | |
| 3a | Maternal acculturation to US x Country of residence | | | | | 0.67 | (-0.55, 1.90) |

*p ≤0.05; **p ≤0.01

[a]Model fit: $F$ (5, 84) = 6.42, p <0.05

[b]Model fit: $F$ (7, 82) = 5.29, p <0.05

[c]Model fit: $F$ (8, 81) = 4.79, p <0.05

**Table 2.3.** Regression coefficients of the associations between maternal acculturation to the Mexican culture with children's measurements of body fat

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.28$ | | | | | |
| 1b | Sex (ref. male) | 0.67 | (-0.23, 1.57) | 0.59 | (-0.32, 1.50) | 0.60 | (-0.34, 1.54) |
| | Age | 0.98* | (0.28, 1.67) | 1.18* | (0.42, 1.95) | 1.18* | (0.41, 1.95) |
| | Sex-specific height-for-age percentile | 0.03** | (0.02, 0.05) | 0.03** | (0.02, 0.05) | 0.03** | (0.02, 0.05) |
| | Mother's years of education completed | 0.01 | (-0.14, 0.15) | 0.00 | (-0.14, 0.14) | 0.00 | (-0.14, 0.14) |
| | Family Nutrition and Physical Activity (FNPA) | 0.04 | (-0.01, 0.09) | 0.04 | (-0.02, 0.10) | 0.04 | (-0.02, 0.10) |
| | | | | $R^2 = 0.30$ | | | |
| 2b | Maternal acculturation to Mexico | | | 0.07 | (-0.76, 0.91) | 0.04 | (-1.08, 1.17) |
| | Country of residence (ref. Mexico) | | | -0.77 | (-2.05, 0.52) | -1.03 | (-8.23, 6.16) |
| | | | | | | $R^2 = 0.30$ | |
| 3b | Maternal acculturation to Mexico x Country of residence | | | | | 0.06 | (-1.55, 1.67) |

*p ≤0.05; **p ≤0.01

[a]Model fit: $F$ (5, 83) = 6.56, p <0.001

[b]Model fit: $F$ (7, 81) = 4.94, p <0.001

[c]Model fit: $F$ (8, 80) = 4.27, p <0.001

**Table 2.4.** Regression coefficients of the associations between maternal acculturation to the US culture with children's measurements of truncal fat

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.63$ | | | | | |
| 1 | Sex (ref. male) | -0.66* | (-1.09, -0.22) | -0.69* | (-1.14, -0.25) | -0.68* | (-1.13, -0.24) |
| | Age | 1.28** | (0.94, 1.62) | 1.20** | (0.84, 1.56) | 1.21** | (0.85, 1.58) |
| | Sex-specific height-for-age percentile | 0.03** | (0.02, 0.04) | 0.03** | (0.02, 0.04) | 0.03** | (0.02, 0.04) |
| | Mother's years of education completed | 0.00 | (-0.07, 0.07) | -0.01 | (-0.08, 0.06) | -0.01 | (-0.08, 0.06) |
| | Family Nutrition and Physical Activity (FNPA) | 0.01 | (-0.02, 0.04) | 0.01 | (-0.02, 0.03) | 0.01 | (-0.02, 0.03) |
| | | | | $R^2 = 0.65$ | | | |
| 2a | Maternal acculturation to the US | | | 0.20 | (-0.12, 0.53) | 0.31 | (-0.14, 0.75) |
| | Country of residence (ref. Mexico) | | | 0.05 | (-0.67, 0.76) | 0.49 | (-0.97, 1.95) |
| | | | | | | $R^2 = 0.65$ | |
| 3a | Maternal acculturation to US x Country of residence | | | | | -0.21 | (-0.81, 0.39) |

*p ≤0.05; **p ≤0.01

[a]Model fit: $F$ (5, 84) = 29.15, p <0.05

[b]Model fit: $F$ (7, 82) = 21.46, p <0.05

[c]Model fit: $F$ (8, 81) = 18.72, p <0.05

**Table 2.5.** Regression coefficients of the associations between maternal acculturation to the Mexican culture with children's measurements of truncal fat

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.63$ | | | | | |
| 1b | Sex (ref. male) | -0.66* | (-1.10, -0.22) | -0.63* | (-1.07, -0.18) | -0.62* | (-1.08, -0.16) |
| | Age | 1.28** | (0.94, 1.62) | 1.19** | (0.82, 1.57) | 1.19** | (0.81, 1.57) |
| | Sex-specific height-for-age percentile | 0.03** | (0.02, 0.04) | 0.03** | (0.02, 0.04) | 0.03** | (0.02, 0.04) |
| | Mother's years of education completed | 0.00 | (-0.07, 0.07) | 0.00 | (-0.07, 0.07) | 0.00 | (-0.07, 0.07) |
| | Family Nutrition and Physical Activity (FNPA) | 0.01 | (-0.02, 0.04) | 0.01 | (-0.02, 0.04) | 0.01 | (-0.03, 0.04) |
| | | | | $R^2 = 0.64$ | | | |
| 2b | Maternal acculturation to Mexico | | | 0.03 | (-0.38, 0.44) | 0.01 | (-0.55, 0.56) |
| | Country of residence (ref. Mexico) | | | 0.35 | (-0.28, 0.98) | 0.16 | (-3.38, 3.70) |
| | | | | | | | $R^2 = 0.64$ |
| 3b | Maternal acculturation to Mexico x Country of residence | | | | | 0.04 | (-0.75, 0.84) |

*p ≤0.05; **p ≤0.01

[a]Model fit: $F$ (5, 83) = 28.77, p <0.001

[b]Model fit: $F$ (7, 81) = 20.57, p <0.001

[c]Model fit: $F$ (8, 80) = 17.78, p <0.001

**Table 2.6.** Regression coefficients of the associations between maternal acculturation to the US culture with children's measurements of lean mass

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.82$ | | | | | |
| 1 | Sex (ref. male) | -0.71** | (-1.02, -0.41) | -0.69** | (-1.01, -0.38) | -0.69** | (-1.01, -0.38) |
| | Age | 1.33** | (1.09, 1.56) | 1.26** | (1.01, 1.51) | 1.26** | (1.00, 1.51) |
| | Sex-specific height-for-age percentile | 0.04** | (0.03, 0.04) | 0.04** | (0.03, 0.04) | 0.04** | (0.03, 0.04) |
| | Mother's years of education completed | -0.04 | (-0.09, 0.01) | -0.04 | (-0.09, 0.01) | -0.04 | (-0.09, 0.01) |
| | Family Nutrition and Physical Activity (FNPA) | 0.01 | (-0.01, 0.03) | 0.01 | (-0.01, 0.03) | 0.01 | (-0.01, 0.03) |
| | | | | $R^2 = 0.82$ | | | |
| 2a | Maternal acculturation to the US | | | 0.01 | (-0.22, 0.23) | 0.01 | (-0.30, 0.33) |
| | Country of residence (ref. Mexico) | | | 0.27 | (-0.23, 0.77) | 0.29 | (-0.73, 1.32) |
| | | | | | | $R^2 = 0.82$ | |
| 3a | Maternal acculturation to US x Country of residence | | | | | -0.01 | (-0.43, 0.41) |

**p ≤0.01

[a]Model fit: $F$ (5, 84) = 76.26, p <0.05

[b]Model fit: $F$ (7, 82) = 54.77, p <0.05

[c]Model fit: $F$ (8, 81) = 47.34, p <0.05

**Table 2.7.** Regression coefficients of the associations between maternal acculturation to the Mexican culture with children's measurements of lean mass

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2$ = 0.82 | | | | | |
| 1b | Sex (ref. male) | -0.71** | (-1.02, -0.40) | -0.68** | (-0.99, 0.37) | -0.70** | (-1.02, -0.38) |
| | Age | 1.32** | (1.09, 1.56) | 1.24** | (0.98, 1.50) | 1.24** | (0.98, 1.50) |
| | Sex-specific height-for-age percentile | 0.04** | (0.03, 0.04) | 0.04** | (0.03, 0.04) | 0.04** | (0.03, 0.04) |
| | Mother's years of education completed | -0.04 | (-0.09, 0.01) | -0.04 | (-0.08, 0.01) | -0.04 | (-0.09, 0.01) |
| | Family Nutrition and Physical Activity (FNPA) | 0.01 | (-0.01, 0.03) | 0.01 | (-0.01, 0.03) | 0.01 | (-0.01, 0.03) |
| | | | | $R^2$ = 0.82 | | | |
| 2b | Maternal acculturation to Mexico | | | 0.02 | (-0.27, 0.30) | 0.09 | (-0.30, 0.47) |
| | Country of residence (ref. Mexico) | | | 0.32 | (-0.12, 0.76) | 0.96 | (-1.48, 3.40) |
| | | | | | | $R^2$ = 0.82 | |
| 3b | Maternal acculturation to Mexico x Country of residence | | | | | -0.15 | (-0.69, 0.40) |

**$p \leq 0.01$

[a]Model fit: $F$ (5, 83) = 75.19, $p < 0.05$

[b]Model fit: $F$ (7, 81) = 54.27, $p < 0.05$

[c]Model fit: $F$ (8, 80) = 47.10, $p < 0.05$

**Table 2.8.** Regression coefficients of the associations between maternal acculturation to the US culture with children's measurements of blood glucose

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2$ = 0.11 | | | | | |
| 1 | Sex (ref. male) | -1.92 | (-6.60, 2.77) | -1.38 | (-6.20, 3.45) | -1.38 | (-6.24, 3.47) |
| | Age | 3.73* | (0.07, 7.39) | 2.77 | (-1.24, 6.77) | 2.75 | (-1.29, 6.79) |
| | Sex-specific height-for-age percentile | 0.06 | (-0.01, 0.13) | 0.06 | (-0.02, 0.13) | 0.06 | (-0.02, 0.13) |
| | Mother's years of education completed | -0.09 | (-0.84, 0.66) | 0.00 | (-0.78, 0.79) | 0.01 | (-0.78, 0.80) |
| | Family Nutrition and Physical Activity (FNPA) | 0.24 | (-0.06, 0.54) | 0.19 | (-0.13, 0.50) | 0.19 | (-0.13, 0.51) |
| | | | | $R^2$ = 0.13 | | | |
| 2a | Maternal acculturation to the US | | | -1.04 | (-4.69, 2.62) | -1.23 | (-5.96, 3.51) |
| | Country of residence (ref. Mexico) | | | 5.11 | (-2.90, 13.11) | 4.14 | (-12.92, 21.19) |
| | | | | | | $R^2$ = 0.13 | |
| 3a | Maternal acculturation to US x Country of residence | | | | | 0.46 | (-6.71, 7.63) |

*p ≤0.05

[a]Model fit: $F$ (5, 78) = 1.90, p =0.11

[b]Model fit: $F$ (7, 76) = 1.58, p =0.15

[c]Model fit: $F$ (8, 75) = 1.37, p =0.22

**Table 2.9.** Regression coefficients of the associations between maternal acculturation to the Mexican culture with children's measurements of blood glucose

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.11$ | | | | | |
| 1b | Sex (ref. male) | -1.98 | (-6.72, 2.76) | -1.62 | (-6.43, 3.19) | -1.54 | (-6.60, 3.52) |
| | Age | 3.78* | (0.07, 7.49) | 2.81 | (-1.37, 6.99) | 2.77 | (-1.50, 7.05) |
| | Sex-specific height-for-age percentile | 0.06 | (-0.01, 0.13) | 0.06 | (-0.02, 0.13) | 0.06 | (-0.02, 0.13) |
| | Mother's years of education completed | -0.09 | (-0.85, 0.67) | -0.05 | (-0.81, 0.72) | -0.05 | (-0.82, 0.73) |
| | Family Nutrition and Physical Activity (FNPA) | 0.24 | (-0.07, 0.54) | 0.19 | (-0.14, 0.52) | 0.19 | (-0.14, 0.53) |
| | | | | $R^2 = 0.12$ | | | |
| 2b | Maternal acculturation to Mexico | | | -0.32 | (-5.48, 4.85) | -0.46 | (-6.31, 5.40) |
| | Country of residence (ref. Mexico) | | | 3.80 | (-3.45, 11.04) | 0.78 | (-57.42, 58.98) |
| | | | | | | $R^2 = 0.\ 12$ | |
| 3b | Maternal acculturation to Mexico x Country of residence | | | | | 0.68 | (-12.36, 13.73) |

*$p \leq 0.05$

[a]Model fit: $F$ (5, 77) = 1.88, p =0.11

[b]Model fit: $F$ (7, 75) = 1.51, p =0.18

[c]Model fit: $F$ (8, 74) = 1.30, p =0.26

**Table 2.10.** Regression coefficients of the associations between maternal acculturation to the US culture with children's measurements of total cholesterol

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.10$ | | | | | |
| 1 | Sex (ref. male) | -11.92 | (-25.06, 1.22) | -13.12 | (-26.60, 0.37) | -13.29 | (-26.86, 0.29) |
| | Age | 7.57 | (-2.74, .88) | 5.33 | (-5.91, 16.57) | 5.16 | (-6.16, 16.48) |
| | Sex-specific height-for-age percentile | -0.08 | (-0.28, .13) | -0.09 | (-0.29, 0.11) | -0.08 | (-0.29, 0.12) |
| | Mother's years of education completed | -0.64 | (-2.69, .42) | -0.96 | (-3.10, 1.19) | -0.92 | (-3.08, 1.24) |
| | Family Nutrition and Physical Activity (FNPA) | -0.57 | (-1.41, .27) | -0.73 | (-1.61, 0.16) | -0.75 | (-1.65, 0.14) |
| | | | | $R^2 = 0.13$ | | | |
| 2a | Maternal acculturation to the US | | | 5.66 | (-4.39, 15.71) | 3.59 | (-9.66, 16.85) |
| | Country of residence (ref. Mexico) | | | 2.72 | (-19.70, 25.13) | -7.04 | (-53.40, 39.32) |
| | | | | | | $R^2 = 0.13$ | |
| 3a | Maternal acculturation to US x Country of residence | | | | | 4.60 | (-14.49, 23.69) |

[a]Model fit: $F\ (5, 79) = 1.78$, $p = 0.13$

[b]Model fit: $F\ (7, 77) = 1.63$, $p = 0.14$

[c]Model fit: $F\ (8, 76) = 1.44$, $p = 0.19$

**Table 2.11.** Regression coefficients of the associations between maternal acculturation to the Mexican culture with children's measurements of total cholesterol

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2$ = 0.09 | | | | | |
| 1b | Sex (ref. male) | -11.38 | (-24.63, 1.87) | -10.48 | (-23.83, 2.86) | -6.47 | (-20.14, 7.20) |
| | Age | 7.09 | (-3.32, 17.50) | 3.59 | (-8.13, 15.29) | 1.59 | (-10.06, 13.24) |
| | Sex-specific height-for-age percentile | -0.07 | (-0.27, 0.13) | -0.08 | (-0.28, 0.13) | -0.11 | (-0.31, 0.09) |
| | Mother's years of education completed | -0.66 | (-2.72, 1.40) | -0.63 | (-2.70, 1.44) | -0.59 | (-2.62, 1.44) |
| | Family Nutrition and Physical Activity (FNPA) | -0.52 | (-1.37, 0.32) | -0.72 | (-1.64, 0.20) | -0.77 | (-1.67, 0.14) |
| | | | | $R^2$ = 0.11 | | | |
| 2b | Maternal acculturation to Mexico | | | 0.76 | (-13.69, 15.21) | -6.65 | (-22.59, 9.30) |
| | Country of residence (ref. Mexico) | | | 13.17 | (-6.66, 33.01) | -146.57 | (-305, 12.23) |
| | | | | | | $R^2$ = 0.16 | |
| 3b | Maternal acculturation to Mexico x Country of residence | | | | | 36.06* | (0.48, 71.63) |

*p ≤0.05

[a]Model fit: $F$ (5, 78) = 1.53, p =0.19

[b]Model fit: $F$ (7, 76) = 1.35, p =0.10

[c]Model fit: $F$ (8, 75) = 1.73, p =0.10

**Table 2.12.** Regression coefficients of the associations between maternal acculturation to the US culture with children's measurements of HDL-cholesterol

| Model | Independent Variables | Block 1: Control variables[a] | | Block 2: Main Effects[b] | | Block 3: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.06$ | | | | | |
| 1 | Sex (ref. male) | -11.92 | (-25.06, 1.22) | -13.12 | (-26.60, 0.37) | -13.29 | (-26.86, 0.29) |
| | Age | 7.57 | (-2.74, 0.88) | 5.33 | (-5.91, 16.57) | 5.16 | (-6.16, 16.48) |
| | Sex-specific height-for-age percentile | -0.08 | (-0.28, 0.13) | -0.09 | (-0.29, 0.11) | -0.08 | (-0.29, 0.12) |
| | Mother's years of education completed | -0.64 | (-2.69, 1.42) | -0.96 | (-3.10, 1.19) | -0.92 | (-3.08, 1.24) |
| | Family Nutrition and Physical Activity (FNPA) | -0.57 | (-1.41, 0.27) | -0.73 | (-1.61, 0.16) | -0.75 | (-1.65, 0.14) |
| | | | | $R^2 = 0.18$ | | | |
| 2a | Maternal acculturation to the US | | | 5.66 | (-4.39, 15.71) | 3.59 | (-9.66, 16.85) |
| | Country of residence (ref. Mexico) | | | 2.72 | (-19.70, 25.13) | -7.04 | (-53.40, 39.32) |
| | | | | | | $R^2 = 0.18$ | |
| 3a | Maternal acculturation to US x Country of residence | | | | | 4.60 | (-14.49, 23.69) |

[a]Model fit: $F$ (5, 79) = 1.03, p =0.41

[b]Model fit: $F$ (7, 77) = 2.43, p =0.03

[c]Model fit: $F$ (8, 76) = 2.10, p =0.05

**Table 2.13.** Regression coefficients of the associations between maternal acculturation to the Mexican culture with children's measurements of HDL-cholesterol

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.05$ | | | | | |
| 1b | Sex (ref. male) | -2.65 | (-7.32, 2.03) | -1.76 | (-6.09, 2.58) | -2.57 | (-7.08, 1.95) |
| | Age | 2.85 | (-0.83, 6.52) | -0.36 | (-4.17, 3.44) | 0.04 | (-3.81, 3.89) |
| | Sex-specific height-for-age percentile | -0.01 | (-0.08, 0.06) | -0.01 | (-0.08, 0.05) | -0.01 | (-0.07, 0.06) |
| | Mother's years of education completed | 0.26 | (-0.47, 0.99) | 0.30 | (-0.37, 0.98) | 0.30 | (-0.37, 0.97) |
| | Family Nutrition and Physical Activity (FNPA) | 0.06 | (-0.24, 0.36) | -0.11 | (-0.41, 0.20) | -0.10 | (-0.39, 0.20) |
| | | | | $R^2 = 0.22$ | | | |
| 2b | Maternal acculturation to Mexico | | | -0.46 | (-5.15, 4.24) | 1.04 | (-4.22, 6.30) |
| | Country of residence (ref. Mexico) | | | 12.13** | (5.69, 18.57) | 44.43 | (-8.00, 96.86) |
| | | | | | | $R^2 = 0.23$ | |
| 3b | Maternal acculturation to Mexico x Country of residence | | | | | -7.29 | (-19.04, 4.45) |

**$p \leq 0.01$

[a]Model fit: $F$ (5, 78) = 0.84, p =0.53

[b]Model fit: $F$ (7, 76) = 2.97, p <0.01

[c]Model fit: $F$ (8, 75) = 2.80, p <0.01

**Table 2.14.** Regression coefficients of the associations between maternal acculturation to the US culture with children's measurements of LDL-cholesterol

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.07$ | | | | | |
| 1 | Sex (ref. male) | -7.45 | (-21.71, 6.82) | -9.68 | (-24.43, 5.08) | -11.14 | (-25.90, 3.61) |
| | Age | 1.02 | (-10.50, 12.53) | 0.57 | (-12.54, 13.68) | 0.09 | (-12.92, 13.10) |
| | Sex-specific height-for-age percentile | -0.16 | (-0.38, 0.06) | -0.19 | (-0.41, 0.04) | -0.19 | (-0.41, 0.03) |
| | Mother's years of education completed | -0.44 | (-2.69, 1.81) | -0.71 | (-3.01, 1.60) | -0.45 | (-2.76, 1.86) |
| | Family Nutrition and Physical Activity (FNPA) | -0.48 | (-1.36, 0.41) | -0.55 | (-1.48, 0.39) | -0.61 | (-1.54, 0.31) |
| | | | | $R^2 = 0.10$ | | | |
| 2a | Maternal acculturation to the US | | | 7.78 | (-3.71, 19.27) | 1.10 | (-13.41, 15.61) |
| | Country of residence (ref. Mexico) | | | -6.54 | (-30.87, 17.79) | -41.12 | (-93.57, 11.33) |
| | | | | | | $R^2 = 0.13$ | |
| 3a | Maternal acculturation to US x Country of residence | | | | | 16.54 | (-5.74, 38.82) |

[a]Model fit: $F$ (5, 65) = 0.96, p =0.45

[b]Model fit: $F$ (7, 63) = 0.95, p =0.47

[c]Model fit: $F$ (8, 62) = 1.12, p =0.36

**Table 2.15.** Regression coefficients of the associations between maternal acculturation to the Mexican culture with children's measurements of LDL-cholesterol

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2$ = 0.07 | | | | | |
| 1b | Sex (ref. male) | -7.45 | (-21.71, 6.82) | -7.68 | (-22.10, 6.74) | -3.18 | (-18.12, 11.75) |
| | Age | 1.02 | (-10.50, 12.53) | -0.85 | (-14.20, 12.51) | -2.98 | (-16.27, 10.32) |
| | Sex-specific height-for-age percentile | -0.16 | (-0.38, 0.06) | -0.17 | (-0.39, 0.05) | -0.20 | (-0.42, 0.02) |
| | Mother's years of education completed | -0.44 | (-2.69, 1.81) | -0.53 | (-2.81, 1.75) | -0.51 | (-2.75, 1.73) |
| | Family Nutrition and Physical Activity (FNPA) | -0.48 | (-1.36, 0.41) | -0.66 | (-1.64, 0.31) | -0.71 | (-1.67, 0.25) |
| | | | | $R^2$ = 0.09 | | | |
| 2b | Maternal acculturation to Mexico | | | 8.28 | (-6.65, 23.21) | 1.07 | (-15.47, 17.60) |
| | Country of residence (ref. Mexico) | | | 5.11 | (-16.38, 26.61) | -145.26 | (-306.68, 16.17) |
| | | | | | | $R^2$ = 0.14 | |
| 3b | Maternal acculturation to Mexico x Country of residence | | | | | 33.97 | (-2.19, 70.14) |

[a]Model fit: $F$ (5, 65) = 0.96, p =0.45

[b]Model fit: $F$ (7, 63) = 0.86, p =0.54

[c]Model fit: $F$ (8, 62) = 1.22 p =0.30

**Table 2.16.** Regression coefficients of the associations between maternal acculturation to the US culture with children's measurements of triglycerides

| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2$ = 0.04 | | | | | |
| 1 | Sex (ref. male) | 13.82 | (-5.82, 33.47) | 17.73 | (-2.38, 37.84) | 18.18 | (-1.99, 38.36) |
| | Age | 7.45 | (-7.96, 22.86) | 6.62 | (-10.14, 23.38) | 7.07 | (-9.75, 23.89) |
| | Sex-specific height-for-age percentile | 0.04 | (-0.26, 0.34) | 0.06 | (-0.24, 0.36) | 0.05 | (-0.25, 0.35) |
| | Mother's years of education completed | -0.98 | (-4.05, 2.09) | -0.17 | (-3.37, 3.03) | -0.26 | (-3.47, 2.95) |
| | Family Nutrition and Physical Activity (FNPA) | -0.20 | (-1.46, 1.05) | -0.21 | (-1.52, 1.11) | -0.14 | (-1.47, 1.19) |
| | | | | $R^2$ = 0.08 | | | |
| 2a | Maternal acculturation to the US | | | -12.76 | (-27.74, 2.23) | -7.25 | (-26.95, 12.44) |
| | Country of residence (ref. Mexico) | | | 17.58 | (-15.84, 51.01) | 43.58 | (-25.31, 112.47) |
| | | | | | | $R^2$ = 0.09 | |
| 3a | Maternal acculturation to US x Country of residence | | | | | -12.25 | (-40.61, 16.12) |

[a]Model fit: $F$ (5, 79) = 0.69, p =0.63

[b]Model fit: $F$ (7, 77) = 0.91, p =0.51

[c]Model fit: $F$ (8, 76) = 0.88, p =0.53

**Table 2.17.** Regression coefficients of the associations between maternal acculturation to the Mexican culture with children's measurements of triglycerides

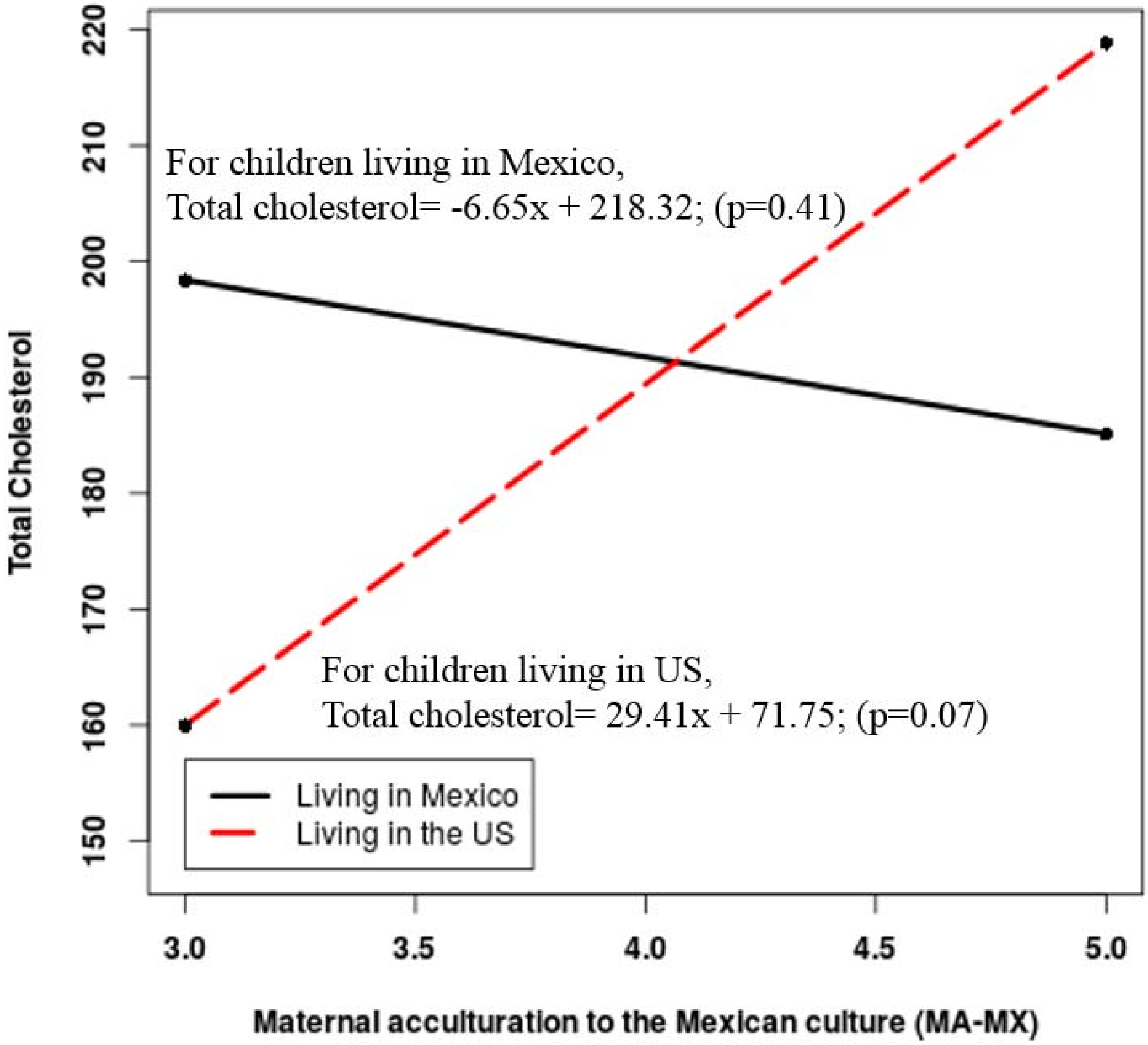
| Model | Independent Variables | **Block 1**: Control variables[a] | | **Block 2**: Main Effects[b] | | **Block 3**: Interaction[c] | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | b | 95% CI | b | 95% CI |
| | | $R^2 = 0.04$ | | | | | |
| 1b | Sex (ref. male) | 13.16 | (-6.67, 32.99) | 13.13 | (-7.07, 33.34) | 17.42 | (-3.56, 38.39) |
| | Age | 8.04 | (-7.55, 23.62) | 8.75 | (-8.97, 26.48) | 6.62 | (-11.25, 24.49) |
| | Sex-specific height-for-age percentile | 0.04 | (-0.27, 0.34) | 0.04 | (-0.27, 0.34) | 0.00 | (-0.31, 0.31) |
| | Mother's years of education completed | -0.95 | (-4.03, 2.13) | -0.93 | (-4.06, 2.20) | -0.89 | (-4.00, 2.23) |
| | Family Nutrition and Physical Activity (FNPA) | -0.25 | (-1.52, 1.02) | -0.19 | (-1.58, 1.21) | -0.24 | (-1.63, 1.15) |
| | | | | $R^2 = 0.04$ | | | |
| 2b | Maternal acculturation to Mexico | | | -2.77 | (-24.64, 19.11) | -10.69 | (-35.15, 13.77) |
| | Country of residence (ref. Mexico) | | | -2.55 | (-32.58, 27.47) | -173.35 | (-416.99, 70.29) |
| | | | | | | $R^2 = 0.07$ | |
| 3b | Maternal acculturation to Mexico x Country of residence | | | | | 38.55 | (-16.03, 93.14) |

[a]Model fit: $F\ (6, 78) = 0.69$, $p = 0.64$

[b]Model fit: $F\ (7, 76) = 0.49$, $p = 0.84$

[c]Model fit: $F\ (8, 75) = 0.68$, $p = 0.71$

**Figure 2.1.** Simple slope of the two-way interaction of maternal acculturation to the Mexican culture with country of residence on total cholesterol. Significant values confirm differences by country of residence.




For children born to Mexican mothers living in Mexico the level of maternal acculturation to the Mexican culture was not associated with their total cholesterol (p >0.05). In contrast, for children living in the US, there was a marginal significance in the association of higher maternal acculturation to the Mexican culture and total cholesterol (p =0.07). This results suggest that higher acculturation to the Mexican culture in mothers living in the US introduces a potential risk to their children's lipid profile. According to Fredrickson DS, Levy RI, Lees RS (1967), in children, total cholesterol levels below 170 mg/dL are considered optimal, and values over 200 are concern and should be monitored [35].

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## CHAPTER 3: Maternal acculturation to the US and obesity risks: Different influences at the cellular level for young children and their mothers of Mexican heritage

### Introduction

Obesity, and obesity-related diseases disproportionately affect Hispanic/Latino adults, particularly Mexicans who account for over 68% of the Hispanic/Latino population in the US [1-3]. It has been suggested that the disparities in the prevalence of obesity and obesity-related diseases among populations of Mexican origin, begin in early childhood, track from adolescence into adulthood, and increase with older age [2, 4]. By the time US Hispanic/Latino children enter kindergarten, 30% have overweight (body mass index, (BMI) >85th Percentile of CDC 2000 Growth Charts), and 17%, have obesity (BMI >95th percentile) [3, 5]. Longitudinal studies suggest that weight status at age 5 predicts weight and metabolic health at age 9 [6]. Adolescents who have overweight or obesity are 18 times more likely to have obesity as adults [7, 8]. Correspondingly, among Hispanic/Latino adults living in the US, it was estimated that in 2014, 39% of males aged 20 to 40 years old, and 51% of females aged 40 to 60 years old had obesity [9]. Overweight and obesity affect 37% of Mexican children aged 5 to 11 [10, 11], and estimates from 2010 indicate that 27% of male, and 37% of female adults had obesity [12].

Epidemiological studies observed that in addition to increasing with age, prevalence of obesity and disease risks increase substantially with higher acculturation to the US culture [2, 4, 13]. In the US, foreign born Mexican children and adults present lower obesity prevalence, and have longer life-expectancy than their native-born counterparts [14-16]. These differences in obesity prevalence and mortality are paradoxical considering foreign-born Mexicans are exposed to greater psychosocial adversity, including, higher stress linked to immigration, higher levels of poverty, lower education, language barriers, marginalization, isolation, and other socioeconomic disadvantages [14-16]. This paradox in health outcomes, also known as the Hispanic health paradox, has been consistently found among foreign-born, and less acculturated Mexican adults [17]. However, the validity of the health paradox among immigrant children, is less conclusive, but the mixed findings may be attributable to changes across the age-spectrum [18].

A potential explanation to the Hispanic health paradox is that disparities are linked to the psychosocial stressors introduced by acculturation processes [19]. Studies of immigrant populations in the US propose that stressors from adapting to new host culture behavioral norms, and values, play a key role in weight gain trajectories, and the development of metabolic dysfunction among Hispanic/Latino immigrants [20]. Prevalence of adverse birth outcomes and obesity rates among Mexican immigrants with greater acculturation are the most salient examples of the Hispanic Health Paradox [17]. Due to disproportionate differences in birth outcomes, it has been proposed that maternal acculturation to the US and Mexican cultures influences offspring's obesity risks through fetal programing [17]. Intergenerational transmission of the psychosocial adversity parents endured may not be limited to fetal programming. Longitudinal data has shown that growing up with a mother who has clinical depression increases risks for obesity in childhood, influences weight outcomes of adolescents, and increases cardiovascular disease risks among young adults [8, 21].

Changes that took place among immigrants experiencing acculturation to the US are currently observed among non-immigrant populations exposed to the US culture remotely, via the wide distribution of the mass media, goods, technology, transnational immigrants, and tourism [22]. New studies that aim to understand the health influence from cultural exposure to the US and the heritage cultures need to expand to include non-immigrant populations experiencing remote acculturation. Thus, the current study investigates the influence of cultural exposure to the US and

Mexican cultures to obesity risks, among immigrant and non-immigrant Mexican mothers and their children. We propose to examine the etiology of the influence of acculturation to obesity risks in childhood, and in adult life, by evaluating how acculturation influences the relationship of telomere lengths, a biological indicator of cellular well-being sensitive to environmental stress; with the percentage of adiposity in weight.

**Telomere lengths and intergenerational influences**

Differences in telomere lengths could help better understand the influence of acculturation in the obesity-related disparities found among Mexican immigrants. Telomeres are segments of DNA that shorten with cell replication, and older age, thus serving as markers of cellular aging [23, 24]. For the most part, telomere lengths are genetically determined [25, 26]. However, lower levels of physical activity, non-exclusive breastfeeding, higher intake of sweet and soda beverages, poor sleep quality, and shorter sleep duration, along with other metabolic complications of obesity have been associated with shorter telomeres [25, 27]. Exposure to chronic physiological stress and social disadvantage can cause telomeres to shorten at an accelerated rate causing premature aging, and increasing vulnerability for obesity, cardiovascular disease (CVD), type 2 diabetes mellitus (T2DM) and other aging-related diseases [24, 25, 28-31]. The influence of stress exposure on telomere erosion can be especially harmful during the first 5 years of life, as this period encompasses a sensitive stage of steepest telomere loss that sets the course for future telomere trajectories [29, 32, 33].

A recent review of factors associated with telomere lengths found that the number of childhood adversities endured, severity and length of exposure have a cumulative effect associated with shorter telomere lengths in adulthood [25]. Several studies of telomere lengths have found evidence of potential intergenerational environmental processes. Parents' environmental exposure to socioeconomic disadvantages, has shown to impact both, the parents, and their offspring's telomere lengths [25, 34]. Among 70 White and Black 7 to 13 years old US children, children born to parents with less than high school education had shorter telomere lengths than children whose parents had a college degree [35]. In a sample of 92 Hispanic/Latino child-mother dyads, researchers found that if mothers experienced chronic depression when the children were 3 year old, both child and mother, had shorter telomere lengths by the time children were 4 and 5 year old [27].

In addition to these outcomes suggesting an intergenerational influence in the relationship between telomere lengths and psychosocial stressors, recent work has called attention to differences by race and ethnicity [36]. In a cross-sectional study examining 1742 White, and 711 Black adults (n=2453), researchers observed that Blacks had longer telomere lengths than Whites [37]. Additionally, while telomere shortening is known to occur with older age, it has been noted that age-related shortening is greater among Blacks and Hispanics compared to Whites [37, 38]. A multiethnic study of adults living in Detroit suggested that racial/ethnic differences attenuated the relationship between low socioeconomic status, and telomere lengths [36]. When compared to non-poor Whites, telomere lengths of poor Whites were shorter [36]. There were no differences in telomere lengths between poor and non-poor Blacks, and contrary to what researchers expected, poor Mexicans had longer telomeres than non-poor Mexicans [36]. Although researchers did not directly measure acculturation among Mexican participants, it was observed that poor Mexicans were more likely to speak Spanish at home and be foreign born, suggesting lower acculturation to the US may have a protective effect on telomere trajectories [36].

**Acculturation and telomere lengths**

Studies examining the association of acculturation with telomere lengths have produced conflicting results. In a previous study of 56 pregnant Mexican and Mexican-American women living in the US, investigators found that acculturation to the mainstream US culture (Anglo), was negatively correlated with telomere lengths and positively correlated with depression [39]. In this study, 70% of the variance in the telomere lengths was explained by higher acculturation to the US, and negative affectivity [39]. Where negative affectivity included measurements of discrimination, depression, and perceived stress [39]. In contrast, in the 'Mano-a-Mano' cohort of 12,792 Mexican American adults aged 20 to 85 year living in the Greater Houston Area, no associations were found between telomere lengths with a variety of proxy measurements of acculturation, including place of birth, language acculturation, number of years living in the US, and age at immigration [40].

In order to advance our knowledge of health disparities it is imperative to better understand the interplay of social and cultural determinants of obesity, and obesity-related diseases among Hispanic/Latino immigrants. Although the Hispanic/Latino Health Paradox resulted from comparative studies of health outcomes across multiple generations of Hispanic/Latino immigrants, analyses of intergenerational interactions are by and large given short shrift, especially in the context of mother-child influences in early childhood. Children inherit not only cells but also behaviors, values and beliefs from their parents with whom they share an environment. Yet, most studies of the relationship between acculturation and health among Latino immigrants have considered the different immigrant generations separately or as isolated individuals, disregarding environmental, social and biological relationships [17]. The analysis of underlying biological and intergenerational associations and differences, influencing disparities in obesity during early childhood could help us better understand how acculturation 'gets under the skin' and introduces risk and protective factors.

This study proposes to examine how the distribution of adiposity in weight (percentage of body fat) is shaped by biological weathering from exposure to psychosocial stressors (telomere lengths) and by cultural influences (to the US, and Mexican culture), in the context of the child-mother relationship. Multiple Actor-Partner Interdependence models (APIMs) will be used to examine two research questions: (1) Is there a child and mother intergenerational relationship between telomere lengths and adiposity? (2) How does maternal acculturation to the US and Mexico contribute to the dynamics between telomere lengths and adiposity? Fig. 1 presents the path model of the child-mother relationships that will be tested.

**Methods**

A purposive sample of 4 to 6 year old child-mother dyads (n =108) were recruited to participate in the Family-based International Evaluation of Salivary Telomere-lengths and Acculturation (FIESTA!). In Mexico, child-mother dyads were recruited from a low-income government funded Preschool-Kindergarten in San Luis Potosí, a semi-urban city. In the US, child-mother dyads were recruited using snowball sampling strategies and referrals from community leaders throughout Central Illinois. Children with cognitive disabilities or congenital disorders that may contribute to the development of obesity were excluded from the study. Informed consent from mothers, and parental consent for children were collected prior to data collection and anthropometric assessments. The FIESTA! Study was approved by the Institutional Review Board of the University of Illinois in Urbana-Champaign, by the Preschool-Kindergarten's Preschool, and by the Secretary General of Education of the State (Secretaría de Educación de Gobierno del Estado, SEGE) in San Luis Potosi, Mexico.

## Measures

### Anthropometric measurements

*Salivary Telomere Lengths (sTL).* Saliva samples from children and mothers were collected to examine telomere length measurements using Oragene™ DNA Self- Collection Kit (Oragene, DNA Genotek, Ottawa, Canada). Saliva samples from Mexico were shipped to the University of Illinois at Urbana-Champaign at room temperature. Upon delivery all saliva samples were stored at room temperature in Dr. Teran-Garcia's Laboratory in the University of Illinois at Urbana-Champaign prior to total DNA analysis in this Laboratory. Total DNA was extracted from 500-µL saliva aliquots using prepIT-L2P (DNA Genotek, ON, Canada), and following manufacturer instructions for DNA precipitation with ethanol by centrifugation.

Concentrations of DNA were normalized at 40ng/uL and stored at -80$^{o}$ prior to shipping all samples on dry ice to the laboratory of Dr. Blackburn at the University of California, San Francisco for salivary telomere assay. The telomere length measurement assay is adapted from the published original method by Cawthon [41, 42]. To control for inter-assay variability, 8 control DNA samples were included in each run. In each batch, the telomeres per single copy gene (T/S) ratio of each control DNA was divided by the average T/S for the same DNA from 10 runs to get a normalizing factor. This was done for all 8 samples and the average normalizing factor for all 8 samples is used to correct the participant DNA samples to get the final T/S ratio. The T/S ratio for each sample is measured twice. Salivary telomere assays were calculated in triplicated and the average of the measurements was used for analyses. Whenever variability exceeded 7%, results were discarded and assays were tested in triplicate again. In this study, the average variability was 2.3%.

*Child and mother height, body composition, and weight status.* Height was measured to the nearest 0.1 cm, using a portable stadiometer with children and mothers in the standing position (Seca 213, Hamburg, Germany). Body composition of children and mothers were collected after overnight fasting, with the Inbody230™ body composition analyzer, which has been validated on both age groups [24, 25]. This body composition assessment provides a validated estimate of total weight, fat-free mass, body fat mass, BMI, and the proportion of adiposity in weight, or percentage of body fat (PBF). Children's BMI-Percentile was calculated using CDC growth charts. BMI and BMI-Percentile measurements were used to determine child and mothers' weight status following CDC criteria [43].

**Mother self-reported data**

*Maternal acculturation*. Maternal acculturation to the US (MA-US), and maternal acculturation to Mexico (MA-MX). Mothers were asked to answer a paper questionnaire that included the revised Acculturation Rating Scale for Mexican Americans (ARSMA-II) [44]. This instrument measures participants' orientation to the Mexican and Anglo cultures separately, and both subscale can be combined to create an overall cultural typology [44]. In response to the recognition of acculturation as a multidimensional concept where greater acculturation to the US culture does not infers the abandonment of the heritage culture [45, 46], in this study the subscales from the ARMSA-II were used to assess Mexican and Anglo orientations independently. This separate examination of two different aspects of acculturation has been recommended to better understand the different associations of acculturation with maternal and child health [46].

To address the lack of items that examine the influence of acculturation on behavioral preferences, items from the subscale 2 were added to the original subscale 1. Exploratory factor analyses were used to examine this revised ARSMA-II scale, and the corresponding association between all items with the two factors of interest: maternal acculturation to the US (MA-US), and maternal acculturation to Mexico (MA-MX).

*Gender and age*. Mothers self-reported the gender (male, female) and continuous age in years of children and themselves. This information was imputed in the body composition machine and collected from mothers responding to the paper questionnaire.

**Analytical approach**

Descriptive statistics of the overall sample, and the subsamples from Mexico and the US were first tested to examine if dyadic data satisfied the normal univariate distribution criteria required for statistical tests. According to Lei and Lomax (2005) skewness and kurtosis values of ±2.3 are problematic [47]. Measurements of acculturation to the US satisfied the criteria and approximate normality (skewness =1.17, kurtosis =1.29). However, measurements of Mexican acculturation were non-normal (skewness =-1.68, kurtosis =4.22). To reduce non-normality in this variable, values were standardized to identify values with a standard deviation ≥2.5, and these outliers (n=3) were excluded from analyses. Upon exclusion of the outliers, the distribution of all measurements of acculturation approximated a normal distribution. Independent samples t-test were conducted to compare the subsample from Mexico and the US. Bivariate Pearson correlation tests were used to examine the correlations between mother and child anthropometric measurements, and the non-independence in the distinguishable dyad. Because of the biological and environmental nature of the child-mother relationships, the anthropometric measurements of the 4 to 6 year old children were expected to be non-independent from their mother's.

The association of each member in the child-mother dyad with their own outcome measurements, and the effects on their partner's outcome measurements were analyzed using the two-intercept Actor-Partner Interdependence Model (APIM) [48]. The APIM statistical methodology accounts for the non-independence in the dyad, and is useful to simultaneously examine potential intergenerational associations between children and mothers [48, 49]. In our analyses, multiple APIMs were used to examine how the percentage of body fat in weight (PBF) is shaped by cellular aging and weathering processes (sTL), and by cultural influences (MA-US, and MA-MX), in the context of the child-mother relationship.

Three separate APIM models were used to test the influence from each maternal cultural orientation in the association of sTL with PBF: (1) MA-US, (2) MA-MX, and (3) MA-US and MA-MX. Independent variables were entered in 3 blocks. In a final model, we used 4 blocks to test the interaction with both, MA-US, and MA-MX. The first model examine the effects of the covariates (gender, and age). Model 2 examined the main effects of child sTL (actor) and mother sTL (partner), controlling for gender and age. In the third models we examined the multilevel interaction with maternal acculturation to the US as level 2 dyadic variable (3a), and maternal acculturation to the Mexican culture as level 2 dyadic variable (3b). Figure 3.1 illustrates the path diagram for these models (3a and 3b). Lastly, we included all variables and tested the simultaneous effect of MA-US and MA-MX in block 4. Results are reported in standardized parameters for the first three models, with PBF (percentage of body fat in weight) as the only outcome tested. Robust errors could not be calculated for the last model. All APIMs were analyzed with hierarchical linear modeling using the APIM two-intercept model method, with restricted maximum likelihood as the estimation method, and percentage of body fat as outcome in HLM 7.03 (Scientific Software

International, Inc; Skokie, IL, US). Given the sample size, the level of significance for all statistical analyses was set at $\alpha \leq 0.05$.

**Results**

Assessment of the psychometric properties of the revised ARSMA-II subscales indicated both had overall high internal consistency and reliability in our sample, with Cronbach's $\alpha$ =0.91 for the MA-US subscale, and Cronbach's $\alpha$ =0.87 for the MA-MX subscale. Based on this results, the revised acculturation subscales were implemented separately in all analyses. Descriptive statistics for children and mother are shown in Table 3.1. Measurements of adiposity and sTL did not differ significantly between children and mother recruited in Mexico and the US. Therefore, data were combined and dyads from both countries were analyzed together.

Pearson correlations were used to examine the relationship between children and mother's anthropometric measurements (results are presented in Table 3.2). The significant correlations between children and mothers measurements of sTL, and fat-free mass warrant the assumption of non-independence in our distinguishable dyad [49]. Correlations between children and mother's sTL are shown in Table 3.2 ($r$ =0.36, $p$ <0.01). Child and mother fat-free mass (mainly muscle) were significantly correlated ($r$ =0.21, $p$ =0.03), but there were no significant correlations between child and mother's PBF ($r$ =0.06, $p$ =0.52).

This study had two primary research questions. First, we wanted to investigate if there was an association between child and mother sTL with their own body fat and with each other's body fat. Results from the APIMs are shown in Table 3.3. Gender and age were significantly associated with children and mother's PBF and added as control variables in all models. Results from actor effects in model 2 show that no significant main effects for sTL emerged for the actor associations predicting their own PBF. The partner effects show no intergenerational effects between children and mother's sTL with each other's adiposity.

In the second research question we examined maternal cultural influences to the US and Mexican cultures and their associations with sTL and adiposity within the context of child-mother relationships. We found a significant cross-level interaction between MA-US with children and mothers' own sTL, and their own PBF. Among children, there was a significant increase in PBF for every unit increase in maternal acculturation to the US and salivary telomere lengths ($b = 5.17$, $SE = 2.50$, $p = 0.04$). Tests of the simple slopes indicated that among children, longer sTL were associated with lower adiposity in weight when their mothers had the lowest maternal acculturation to the US (Figure 3.2 (left); $b = -11.54$, $SE = 3.63$, $p < 0.01$). The simple slopes for children of mothers with moderate or higher levels acculturation to the US were not significant at the $\alpha < 0.05$ level.

In mothers, there was a significant cross-level interaction between mother's body fat, mother's sTL and MA-US ($b = 29.30$, $SE = 7.67$, $p < 0.01$). Tests of the simple slopes exploring this interaction revealed important differences by the degree of MA-US in the associations between mother's sTL with their own adiposity (Figure 3.2 (right)). For mothers with the lowest acculturation to the US, longer sTL were associated with lower adiposity in weight ($b = -23.18$, $SE = 7.52$, $p < 0.01$). In contrast, for mothers with moderate to high MA-US, longer sTL were associated with higher percentages of body fat in weight ($b = 35.42$, $SE = 9.63$, $p < 0.01$ for moderate MA-US, and $b = 94.02$, $SE = 24.47$, $p < 0.01$ for the highest MA-US).

Results from the APIMs used to examine the influence of maternal acculturation to the Mexican culture are shown in Table 3.3. Model 3b revealed that neither actor, nor partner effects, were significant. These indicate that no cross-level interactions were found for MA-MX. Results also show no partner effects, which reveal there were no intergenerational cross-level interactions with MA-MX.

We examined all APIMs interactions further by exploring the effects attributable to differences by country of residence, given the unequal distribution in our sample (results not shown). Results were similar to those of previous tests, with non-significant partner effects, a small difference in the associations identified for children, and no differences in the associations identified for mothers. Among children, a near significant association showed country differences may attenuate the moderating effects of maternal acculturation to the US, in the direct associations of sTL with their own adiposity (b =4.63, SE =2.50, p =0.07).

**Discussion**

Our assessment of the interplay of maternal acculturation to the US and the Mexican culture in the relationship between telomere lengths and adiposity revealed important differences by level of acculturation to the US for children and mothers. Contrary to what we expected, in our sample of children and mothers of Mexican heritage, we found no direct associations between telomere lengths with adiposity, and no intergenerational ‘partner’ associations. The lack of partner effects suggest acculturation to the US influences the associations of children and mothers’ telomere lengths with their own, but not each other’s adiposity.

For mothers and children with the lowest maternal acculturation to the US culture, longer salivary telomere lengths were associated with lower percentages of body fat. In contrast, among mothers with moderate to high acculturation to the US, longer salivary telomere lengths were associated with greater percentage of body fat in weight. We found no statistically significant associations between telomere lengths and percentages of body fat for children with mothers who have moderate to higher maternal acculturation to the US.

**No associations between telomere lengths and adiposity for children and mothers**

Obesity is a state of increased oxidation which impacts telomere erosion processes negatively [50]. However, in our study, telomere lengths were not directly associated with adiposity among mothers or children. Weight gain has been associated with shorter telomere lengths in adolescents and adults, but to date the association is not conclusive because it does not hold consistently across studies [38, 50-52]. In children, the association appears to vary by age, and be stronger among older children, and adolescents. In a multidisciplinary weight loss intervention with adolescents with overweight and obesity, adolescents who underwent a significant weight loss during the intervention presented an increase in telomere lengths [30]. Similarly, in a study of 793 French children ages 2 to 17 with and without obesity, authors found that telomere lengths of children with obesity were 24% shorter than the telomeres of children without obesity [53]. In contrast, a recent longitudinal examination of the relationship between telomere lengths and obesity in Latino children found that telomere lengths were not associated with children's adiposity when children were 4 or 5 years old, but predicted the development of obesity by age 9 [54].

**No intergenerational effects**

Analyses revealed key differences in the cross level interactions of maternal acculturation to the US, with telomere length and adiposity measurements for mothers and children. The lack of partner effects in our assessments may be explained by these differences. In addition, these results suggest children and mothers in our sample have independent cellular aging, and weight gain trajectories, and different vulnerability to higher acculturation to the US, which affected children, but not mothers. All these differences, suggest obesity risks from the cellular level, are mostly linked with environmental, behavioral and sociocultural dynamics and less influenced by genetic inheritance.

Recent studies in Mexico and the US found that Mexican-born children living in the US and Mexico are gaining weight at a much accelerated rate than previous generations (i.e. their parents) [55, 56]. In the US, a recent study using data from the National Health and Nutrition Examination Surveys (NHANES) found that differences in weight gain between Mexican foreign-born and Mexican US-born children shifted in the past 20 years [55]. In recent years Mexican-born 4 to 17 year old children living in the US had the most alarming increases in prevalence of obesity in the US [55]. As a consequence, currently obesity rates of Mexican born are similar to those found among Mexican US-born youth [55]. In Mexico, prevalence of childhood obesity increased by 40% between 1999 and 2006, notably, this is the most rapid rise ever documented worldwide [56]. Correspondingly, the disjuncture found between children and mothers in our sample, maybe explain by these changes in speed of weight gain in childhood, and the underlying causes driving these changes. Our findings suggest that increases in acculturation to the US, by direct exposure, and remotely, may be connected to the underlying causes responsible for the alarming rise in childhood obesity prevalence.

**Low maternal acculturation to the US has a protective effect for both child and mother, and high maternal acculturation to the US affects mothers but not children**

Findings suggest that lower acculturation to the US serves a protective effect against accelerated cellular aging and obesity for mothers and their children. These findings are consistent with previous studies that recognize protective effects and an immigrant advantage for populations with the lowest acculturation to the US, and greater odds for obesity and cardiovascular disease for second and third generation immigrants of Mexican descent [2, 19, 57, 58]. With the caveat that in our study, greater maternal acculturation to the US introduced health risks for mothers but for not for their children.

Compared to previous studies that examined the relationships between acculturation to the US and telomere lengths, our findings partially support the conflicting results from both previous studies. One study found a negative association of acculturation to the US culture with telomere lengths of women who have lived in the US for more than 10 years [39]. We found a similar relationship between higher maternal acculturation to the US culture and shorter telomere lengths in adult women, but not in young children [39].

In contrast, among children, our findings support some of the associations previously identified in the 'Mano-a-Mano' study [40]. The 'Mano-a-Mano' study included 70% foreign-born Mexican adults with varied number of years and age at immigration living in the US, near the US border [40]. Given these characteristics, we presume participants were highly acculturated to the US, and those with the lowest of acculturation to the US in the 'Mano-a-Mano' cohort, parallel children with mothers in the highest acculturation to US culture in our Mexican cohort. Among children of mothers with moderate and high acculturation to the US culture, we found similarities in the lack of associations between telomere lengths with higher acculturation to the US. We also observed from the simple slopes, a non-significant trend among children with the highest acculturation in our sample, that partially supports the positive association found between telomere lengths with body mass index (BMI) in the 'Mano-a-Mano' cohort [40].

Taken together, these conflicting results suggest there are generational differences in the influences, and lack thereof, of acculturation to the US. We found greater acculturation to the US affects mostly adult mothers, but not the children; and given previous study results, possibly adults who have been living in the US for 10 years or more.

**Relationship with the Hispanic health paradox**

A myriad of hypothesis have been proposed to explain differences in health outcomes linked to the Hispanic health paradox. Earlier studies documented dietary, and physical activity patterns that were negatively influenced by higher acculturation to the US culture, and exposure to the US obesogenic environment [4, 22]. In the past 20 years, Mexico underwent rapid industrialization and environmental changes that included increase ease of access and affordability of high-caloric foods, and limited opportunities for physical activity [55]. As a result, the obesogenic environment is currently shared by both counties [55]. Our results suggest that in both of these obesogenic contexts, greater obesity risks are exacerbated by greater cultural affinity with the US culture. Further examination of differences by country revealed that among children, country differences reduced the effect found within the interaction between acculturation to the US, telomere lengths and adiposity (results not shown). However, in the case of mothers, the influence of maternal acculturation to the US on women's health outcomes persisted independent of country differences. Unfortunately, the lack of country effects suggests the extent to which remote acculturation to the US culture introduces obesity risks to Mexican women living in semi-urban cities in Mexico, is similar to the risks observed among women of Mexican heritage living in the US.

Currently, the prevailing explanation for the immigrant advantage is that psychosocial factors such as optimism, stronger social support from families, and social ties, buffer stress and afford a protective effect against social disadvantage [19]. Many of these studies established associations between psychosocial protective factors with the Mexican culture [19]. Our results partially advance this explanation by providing support for telomere lengths as a potential mechanism through which excessive stress introduced by the lifestyle demands from higher acculturation to the US culture 'gets under the skin' and affects not only mothers' but their children's body composition and cellular health. However, we did not found any protective effects associated with the Mexican culture. In our study, acculturation to the Mexican culture was not associated with children or mother cellular health or body composition. Yet, given our limited sample size, it is possible that cultural and psychosocial dynamics from the Mexican culture that may play a protective role were not detected. It is also possible that the influences from cultural protective and risk factors are not observable in the relationship between telomere lengths and adiposity in early childhood, but are associated with future telomere length and adiposity risks [54].

**Study limitations and future recommendations**

Study results, and the implications that emerged from the associations identified, should be taken with caution given the limited subgroup sample size, the unequal distribution in our sample, and the different exposures to acculturation across country subgroups, age groups, and individuals. Another limitation was that we focus on the relationship of young children with their mothers, and the contribution from fathers, siblings, and other family members was omitted. Previous studies have observed mother influence on child's weight status is greater than fathers' contribution [59]. It is important to recognize that all family members may play an important role in children's cultural socialization, as well as in the development of behaviors linked to obesity. Future analyses should consider assessing the role of acculturation, and their corresponding influences on telomere lengths with adiposity measurements with different family members, in the context family-cluster relationships. Father factors, particularly fathers' age at conception, and presence in child's life, have shown to influence child telomere lengths, and obesity risk [60-62]. Further exploring family relationships at the biological and social levels can introduce important information about the differences in susceptibility to cultural determinants of obesity within the family context.

To our knowledge, despite the importance of early life for obesity risks, previous work has not directly examined the potential intergenerational associations of acculturation, with telomere lengths, and obesity risks in young children. Studies among immigrant and non-immigrant populations near the US/Mexico border, or immigrants living in ethnic enclaves in the US may yield different results, given the different gradient of cultural exposure to both the US and Mexican cultures. We recommend future studies continue the focus on biological measurements, as studies that include biological assessments can introduce information that can help public health professionals address health disparities. Future research should further explore how positive emotion and resiliency may be linked to acculturation processes and its effects on telomere lengths, and obesity. The identification of positive emotion aspects related to acculturation could inform the development of appropriate interventions.

## Conclusion

Obesity is a complex, chronic health problem influenced by genetic and biologic risk factors, exacerbated by environmental, behavioral and sociocultural dynamics [63, 64]. Our results suggests that acculturation to the US influences the associations between telomere shortening with adiposity among Mexican mothers, and their young children. Among children and mothers with the lowest level of acculturation to the US, longer telomere lengths were associated with lower adiposity in weight. This finding provides partial supporting for the presence of the Hispanic Health Paradox at the cellular and biological level. We found no evidence of intergenerational associations. To the contrary, we found the psychosocial stressors introduced by the lifestyle demands of the US culture influence mother's health but not their young children. While we cannot discount the role of genetics in the associations between telomere lengths with adiposity, it is likely that socio-cultural environmental factors are mostly responsible for the divergence in adiposity accumulation we report. Future studies are needed to uncover the underlying behavioral mechanisms linked to the rises in obesity prevalence, and disjuncture in the association between children and mother's telomere lengths with their adiposity trajectories. The identification of modifiable factors can guide family-based, culturally-sensitive, lifestyle interventions that aim to limit the negative influence that greater acculturation to the US has upon the health of children of Mexican heritage living in Mexico and the US.

## Tables and Figures

**Table 3.1.** Mother and Child Characteristics

| **Characteristics** | All (n=108) | Mexico (n=78) | US (n=30) |
|---|---|---|---|
| **Child Characteristics** | | (%, (n)/ *m* ±sd | |
| Children's age** | 4.58 ±.73 | 4.4 ±.5 | 5.1 ±0.9 |
| 4 years old | 55.6 (60) | 64.1 (50) | 33.3 (10) |
| 5 years old | 30.6 (33) | 33.3 (26) | 7 (23.3) |
| 6 years old | 13.9 (15) | 2.6 (2) | 13 (43.3) |
| Children's gender (Male) | 49.1 (53) | 46.2 (36) | 56.7 (17) |
| Children's Percentage of Body Fat | 26.96 ±7.2 | 27.3 ± 6.9 | 25.98 ± 7.5 |
| Sex-specific children's BMI-for-age Percentile | 63.9 ±30.36 | 60.6 ±32.0 | 72.5 ± 23.9 |
| Children's Weight Status | | | |
| Normal (5$^{th}$ to 84.9$^{th}$ percentile) | 66.7 (72) | 67.9 (53) | 63.3 (19) |
| Overweight (85$^{th}$ to 94.9$^{th}$ percentile) | 13.9 (15) | 12.8 (10) | 16.7 (5) |
| Obese (>95$^{th}$ percentile) | 19.4 (21) | 19.2 (15) | 20.0 (6) |
| Children's salivary telomere lengths (T/S) | 1.69 ±.28 | 1.70 ±.30 | 1.36 ±.23 |
| Telomere length by age group (T/S) | | | |
| 4 years old | 1.71 ±.29 | 1.71 ±.30 | 1.70 ±.23 |
| 5 years old | 1.68 ±.28 | 1.69 ±.29 | 1.64 ±.27 |
| 6 years old | 1.62 ±.28 | 1.44 ±.43 | 1.66 ±.26 |
| **Mother Characteristics** | | | |
| Mother's age (range 19 -55) | 30 ±.6.53 | 29 ±7 | 32 ±5 |
| Under 25 | 30.6 (33) | 39.7 (31) | 6.7 (2) |
| 25-30 | 21.3 (23) | 17.9 (14) | 30 (9) |
| 31-35 | 21.3 (23 | 16.7 (13) | 33.3 (10) |
| 35 and older | 20.4 (22) | 20.5 (16) | 20 (6) |
| Mother's Percentage of Body Fat | 38.97 ±6.17 | 38.20 ±6.20 | 40.20 ±6.3 |
| Mother's BMI | 27.52 ± 4.53 | 27.33 ±7.01 | 27.98 ±7.52 |
| Mother's Weight Status | | | |
| Normal | 25.9 (28) | 33.3 (26) | 6.7 (2) |
| Overweight | 25.9 (28) | 24.4 (19) | 30.0 (9) |
| Obese | 41.7 (45) | 37.2 (29) | 53.3 (16) |
| Mother's salivary telomere lengths (T/S) | 1.33 ±.21 | 1.36 ±.23 | 1.28 ±.13 |
| Telomere length by age group (T/S) | | | |
| Under 25 | 1.41 ±.25 | 1.41 ±.25 | 1.22 ±.02 |
| 25-30 | 1.31 ±.16 | 1.29 ±.19 | 1.35 ±.12 |
| 30-35 | 1.32 ±.22 | 1.35 ±.22 | 1.25 ±.16 |
| 35 and older | 1.30 ±.19 | 1.32 ±.22 | 1.24 ±.07 |
| Mother's acculturation to US culture (ARSMA-II)** | 2.17 ±1.07 | 1.69 ±.63 | 3.07 ±1.15 |
| MA-US range (ARSMA-II) | 1.0 to 5.0 | 1.0 to 4.0 | 1.55 to 5.0 |
| Mother's acculturation to the Mexican culture (ARSMA-II)* | 4.67 ±.56 | 4.79 ± .33 | 4.37 ±.86 |
| MA-Mexico culture range (ARSMA-II) | 1.42 to 5.0 | 3.75 to 5.0 | 1.42 to 5.0 |

*p <0.05; ** p <0.001

**Table 3.2.** Bivariate correlations among children and mother anthropometric measurements

| | | Mother measurements | | | | | Child measurements | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| **Mother measurements** | | | | | | | | | | | | |
| 1 | Salivary telomere lengths (sTL) | -.009 | -.152 | -.154 | -.065 | -.096 | .363** | .109 | -.15 | -.205* | -.032 | -.051 |
| 2 | Percentage of body fat (PBF) | -- | .494** | .027 | .760** | .706** | -.022 | .063 | .09 | .065 | .100 | .064 |
| 3 | Weight (kg) | | -- | .834** | .894** | .870** | .048 | -.017 | .176 | .211* | .108 | .14 |
| 4 | Fat-free mass (kg) | | | -- | .501** | .509** | .009 | .006 | .17 | .213* | .099 | .143 |
| 5 | Body-fat mass (kg) | | | | -- | .952** | .03 | .03 | .121 | .12 | .103 | .056 |
| 6 | Body mass index (BMI) | | | | | -- | -.011 | -.027 | .148 | .166 | .094 | .102 |
| **Child measurements** | | | | | | | | | | | | |
| 7 | Salivary telomere lengths (sTL) | | | | | | -- | .069 | -.077 | -.113 | -.016 | -.057 |
| 8 | Percentage of body fat (PBF) | | | | | | | -- | .478** | .085 | .841** | .616** |
| 9 | Weight (kg) | | | | | | | | -- | .902** | .859** | .650** |
| 10 | Fat-free mass (kg) | | | | | | | | | -- | .566** | .486** |
| 11 | Body-fat mass (kg) | | | | | | | | | | -- | .690** |
| 12 | Sex-specific body mass index-for age percentile (BMI-P) | | | | | | | | | | | -- |

*$p$ <0.05; **$p$ <0.01

**Table 3.3.** Robust coefficients for the child-mother dyadic association between salivary telomere lengths and percentage of body fat in weight from four two-intercept Actor-Partner Interdependence Models

| | Model 1: Covariates | | Model 2: Tests of STL | | Model 3a: Moderation of MA-US | | Model 3b: Moderation of MA-MX | | Model 4: Moderation of MA-US/ MA-MX[a] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | β | (SE) | β | (SE) | β | (SE) | β | (SE) | b[a] | (SE) |
| Gender | 35.44** | 1.11 | | | | | | | | |
| Age | -0.08 | 0.11 | | | | | | | | |
| **Intercepts** | | | | | | | | | | |
| Mother | | | 14.62* | 6.05 | | | | | | |
| Child | | | 25.69** | 5.40 | | | | | | |
| **Actor effects** | | | | | | | | | | |
| Mother sTL → Mother's PBF | | | 2.97 | 2.90 | -6.62 | 5.63 | -55.46 | 56.25 | -86.90 | 61.57 |
| Child → Child's PBF | | | -0.13 | 4.11 | -52.48** | 14.66 | 65.64 | 41.45 | 19.30 | 78.48 |
| **Interaction Actor Effects** | | | | | | | | | | |
| MA-US * Mother sTL → Mother's PBF | | | | | 5.17* | 2.50 | | | 6.36 | 3.79 |
| MA-US * Child → Child's PBF | | | | | 29.30** | 7.67 | | | 30.17** | 9.02 |
| MA-MX * Mother sTL → Mother's PBF | | | | | | | 12.23 | 11.74 | 16.18 | 12.13 |
| MA-MX * Child → Child's PBF | | | | | | | 13.24 | 8.71 | -14.95 | 15.40 |
| **Partner effects** | | | | | | | | | | |
| Mother sTL → Child's PBF | | | 3.03 | 4.76 | -4.14 | 5.42 | 47.20 | 89.97 | 21.74 | 87.35 |
| Child sTL → Mother's PBF | | | 3.05 | 3.22 | 7.71 | 7.36 | -8.04 | 34.70 | -42.43 | 56.32 |
| **Interaction Partner Effects** | | | | | | | | | | |
| MA-US * Mother sTL → Child's PBF | | | | | 4.03 | 4.95 | | | 4.12 | 6.10 |
| MA-US * Child sTL → Mother's PBF | | | | | -3.95 | 2.62 | | | -2.81 | 3.57 |
| MA-MX * Mother sTL → Child's PBF | | | | | | | -9.23 | 18.50 | -5.28 | 16.98 |
| MA-MX * Child sTL → Mother's PBF | | | | | | | 2.34 | 7.47 | 10.03 | 11.08 |

*p <.05; **p <0.001

[a]Robust errors could not be calculated for this model.

**Figure 3.1.** Actor-partner interdependence model (APIM) to examine the influence of maternal acculturation to the US on the associations between child (actor) and mother (partner) salivary telomere lengths with child and mother's percentage of body fat in weight.

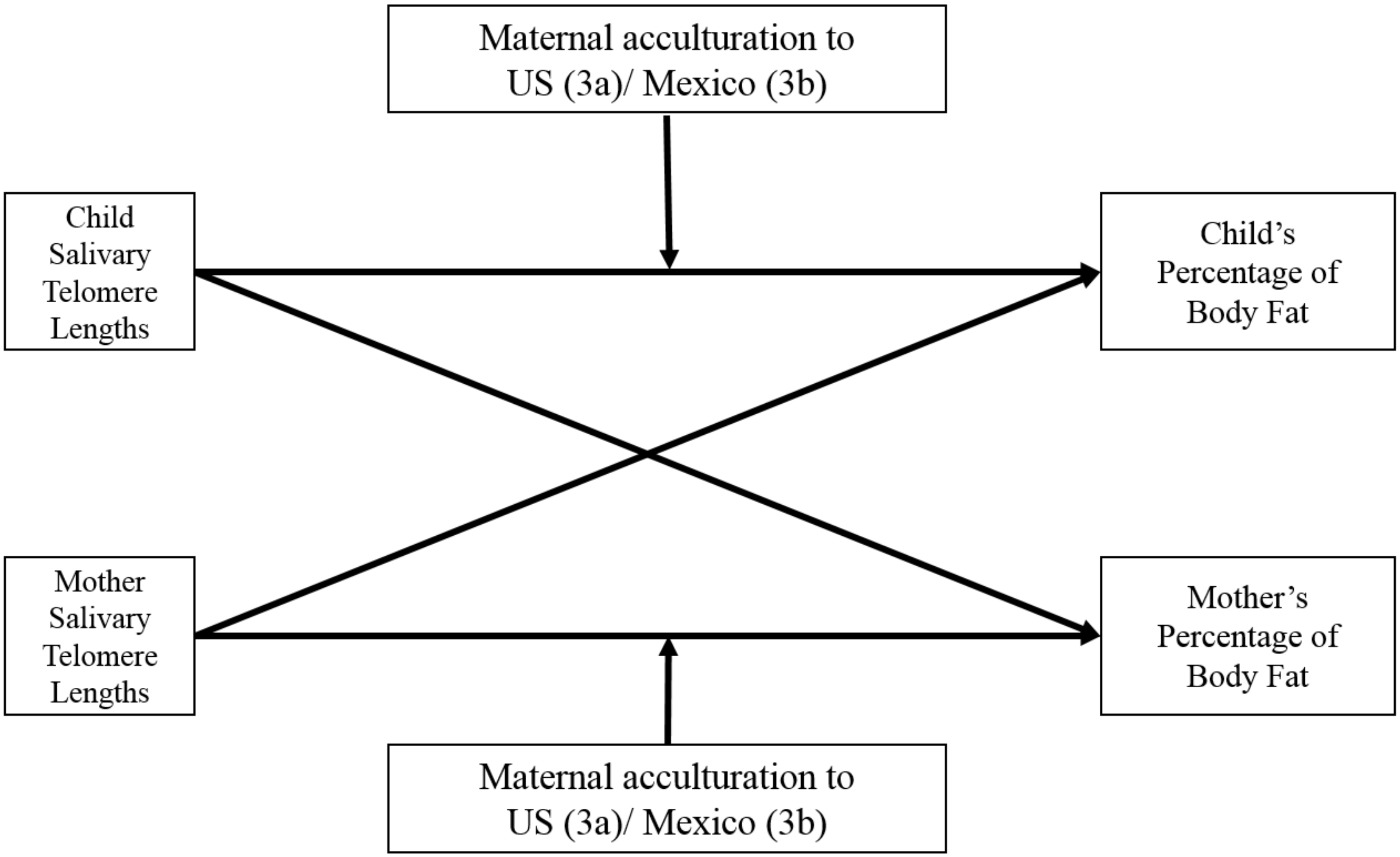
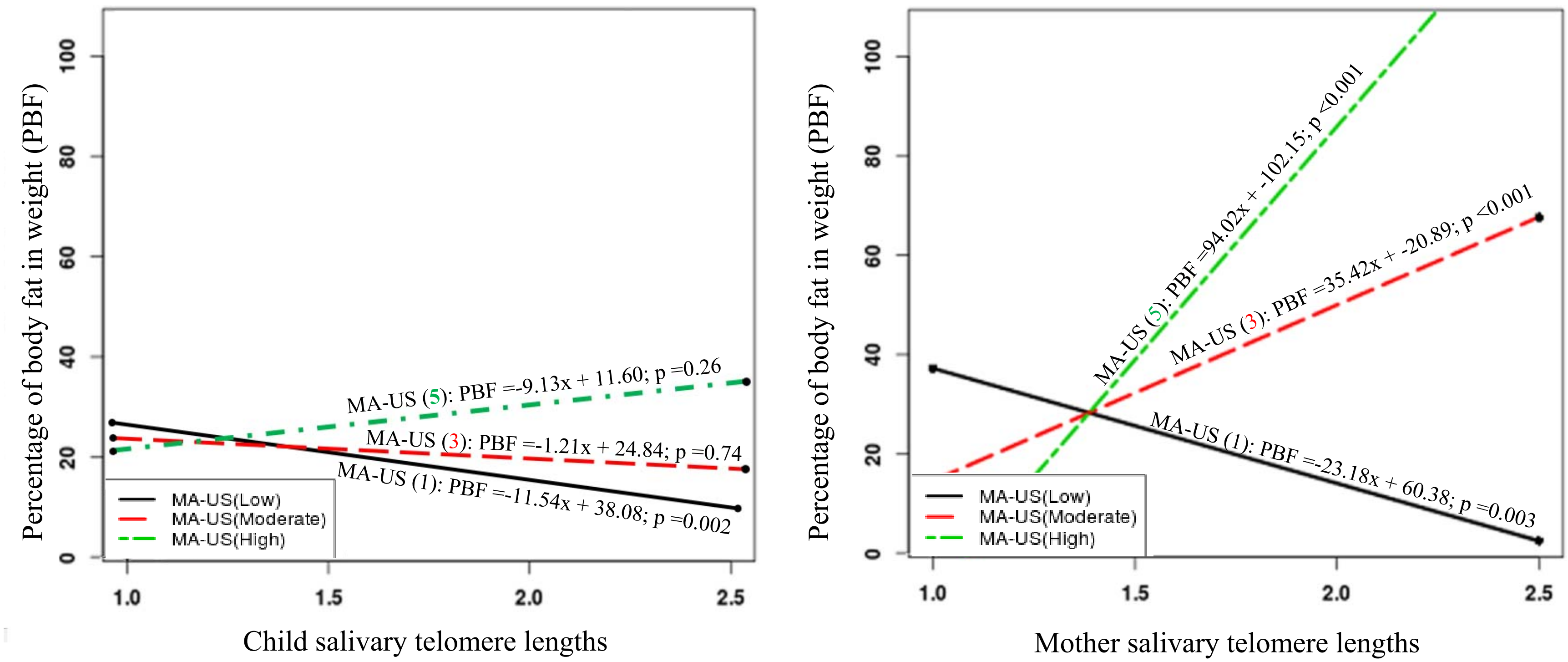


**Figure 3.2.** Simple intercepts and slopes of the predicted percentages of body fat in weight interactions with mother and child's salivary telomere lengths by three levels of influence of maternal acculturation to the US culture




The association between salivary telomere lengths with percentage of body fat in weight (PBF) varies by level of maternal acculturation to the US culture and affects children and mothers differently. Among children (left) when maternal acculturation to the US is low, longer telomere lengths are significantly associated with lower PBF. In contrast, for children who have a mother with high or moderate acculturation to the US, their salivary telomere lengths are not associated with their PBF. Among mothers (right), longer salivary telomere lengths are associated with a higher PBF when mothers have high or moderate maternal acculturation to the US (scores of 5 and 3 in the ARSMA-II subscale respectively). In contrast, when mothers have low maternal acculturation to the US (score of 1 in the ARSMA-II subscale), longer salivary telomere lengths are associated with a lower PBF.

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## CHAPTER 4: Influences of maternal acculturation on obesity risks of young children of Mexican heritage: from telomere lengths to health behaviors

### Introduction

Early childhood obesity is one of the major health problems in the US and Mexico. In the US, although there is some evidence suggesting that childhood obesity rates may be levelling off [1, 2], obesity continues to increase among Mexican American children [3]. In Mexico, between 1999 and 2006, obesity prevalence in children ages 5 to 11 years old rose by 40%, documenting the fastest increase worldwide [4]. Mounting evidence suggests obesity prevalence among Mexican young children increases with US-nativity, because of higher acculturation to the US culture [5]. However, a recent study that examined national prevalence of obesity in the US among young children found that foreign born Mexican youth no longer exhibit a health advantage compared to US-born Mexican youth [4].

A possible explanation for the loss of the immigrant advantage in obesity among Mexican-American youth could be linked to changes in acculturation processes. A complex process by which immigrants gradually modify their attitudes and behaviors linked to their heritage culture, and adopt new ones from the host culture [6]. Currently, the expansion of technological advances, globalization-driven exchanges, and social media communications, have enabled an increasing exposure of the US culture. As a result, acculturation processes previously experienced by immigrant populations, are now be experienced by non-immigrant populations undergoing through similar *remote acculturation* processes [7, 8]. Much less is known about the health influences of the remote acculturation processes. Recent studies have documented that Jamaican non-immigrants are exposed to the US culture through remote channels (i.e. cable television, tourism, social media, etc.) [8]. Further reviews of the remote acculturation processes revealed that among Jamaican non-immigrants, a higher connection with the US culture is associated with higher intake of unhealthy foods, and increased risks for obesity [8, 9].

Given its geographic proximity, and intertwined economic and social relationships, exposure to the US culture via remote acculturation may be most prominent among Mexican children and adults. For the US, Mexico is the third largest economic partner, and the top origin country of the foreign-born population. Mexican-born children and adults in the US currently account for 11.6% of the US population [10-12]. For Mexico, the US is its top economic partner, and top immigration destination. The Inter-American Development Bank estimated that about 10% of Mexican families, and 20% of the country's poorest rural communities depend on the remittances sent from immigrant workers in the US [11, 12]. This close relationship between both countries lead us to suggest that higher acculturation to the US culture among Mexican families is associated with the alarming rises in early childhood obesity prevalence among children of Mexican heritage living in Mexico and the US. Family is the most important social context where children learn and adopt health behaviors [13]. Mothers, more often than fathers engage in a wide variety of behaviors that influence their children's preferences, health habits, and obesity risks [13-15]. Based on these, we hypothesized that socio-cultural determinants of health begin influencing obesity risks in early childhood through earlier influences transmitted from Mexican mothers to their young children via efforts to culturally socialize children, the family environment offered to them, and health behaviors promoted. Because of remote channels of acculturation, we anticipate the influences from maternal socio-cultural determinants of health will be independent of country of residence. Thus, this study examines how exposure to the US and Mexican cultures shape family environmental and behavioral factors to influence young children's obesity risks from the chromosome level to their adiposity accumulation and weight status.

Telomere lengths are protein caps at the end of the chromosomes responsible for preventing spontaneous DNA damage [16]. In adults, shorter telomeres are associated with increased acculturation to the US, obesity-related health behaviors, and future cardiovascular disease [17-23]. Far fewer studies have examine telomeres in early childhood, notwithstanding telomere erosion can be especially harmful during the first 5 years of life, as this period encompasses a sensitive stage of steepest telomere loss that sets the course for future telomere trajectories [24-26]. Of the studies that have examined telomere lengths in early childhood, one study of Latino children in the US, found that shorter telomere lengths at age 4 and 5 were associated with higher intake of sweet and soda beverages, and obesity by age 9 [27]. While this previous study examined the associations of telomere lengths with young children's obesity risks, and one behavioral risk factor (intake of sweet and soda beverage), to our knowledge, no study has analyzed the joint influence of socio-cultural and behavioral factors of obesity.

The purpose of this study is to examine the influence of maternal acculturation to the US and the Mexican cultures during early childhood in the context of the bio-behavioral associations between family environmental and behavioral factors with three biological outcomes: (1) telomere lengths, (2) body fat mass, and (3) sex specific body mass index-for-age-percentile (BMI-P).

## Methods

### Study population

The Family-based International Evaluation of Salivary Telomere Lengths and Acculturation study (FIESTA!) investigated a cohort of 108 children with an age between 4 to 6 years old, born to Mexican mothers. A purposive sample of low-income children were recruited from a government funded kindergarten in a low income community in San Luis Potosí, Mexico (n =78), and through community referrals, and use of snowball sampling strategies in Central Illinois, US (n =30). Mothers were asked to complete a paper-based questionnaire in their language of preference (Spanish or English). Anthropometric measurements were collected in the morning after an 8-hour fasting. Written consent, and parental consent was obtained from all mothers, and verbal assent from all children prior to participation. The research protocol was approved by the Institutional Review Board (IRB) at the University of Illinois in Urbana-Champaign, and the Kindergarten principal, with the endorsement Secretary General of Education of the State (*Secretaría de Educación de Gobierno del Estado, SEGE*) in San Luis Potosi, Mexico.

**Independent variables**

**Family environmental and behavioral factors (FNPA)**

To evaluate the family environmental and behavioral factors we used the Family Nutrition and Physical Activity (FNPA) screening tool administered with mothers in the paper questionnaire format [28]. The FNPA screening tool evaluates 10 family-based environmental and behavioral factors that influence childhood obesity risks [28]. These environmental and behavioral factors were identified in an Academy of Nutrition and Dietetics Evidence Analysis, and are captured within 20 items that evaluate home obesogenic environments and parenting practices associated with childhood risk for overweight, increased body fat, changes in BMI, cardiovascular disease, and acanthosis nigricans [29-31]. In this scale, each factor is evaluated by the mean score of two items. Scores are reverse when needed so that higher score indicate more desirable, or healthier environments and behaviors [28]. The 10 factors examined include: (1) Family meals (breakfast habits, and eating meals together); (2) Family eating practices; (3) Food choices; (4) Beverage choices; (5) Food restrictions, or uses of food to reward good behavior; (6) Family regulations of screen time; (7) Healthy environment, which refers to whether the child has access to screens or monitors in his/her bedroom, and whether the family provides opportunities for physical activity; (8) Family support for physical activity; (9) Child physical activity, and (10) Family sleep routine habits, which assess how often children follow a bedtime routine and child length of sleep at night.

**Potential Moderators**

Maternal acculturation to the US culture (MA-US) and maternal acculturation to the Mexican culture (MA-MX)

Mothers were asked to answer a paper questionnaire that included the Acculturation Rating Scales for Mexican Americans-II (ARSMA-II) [32]. ARSMA-II uses a scale from 1 (not at all) to 5 (extremely often or always) to measures cultural factors like language preferences, ethnic pride and identity, cultural interactions, among others. Since few items examined behaviors linked to obesity, mothers were asked to complete subscale 1, and additional items that addressed dietary preferences from subscale 2.

Following ARSMA-II guidelines, mothers received linear acculturation scores for acculturation to the US culture, and for acculturation to the Mexican culture. Exploratory factor analyses, and examination of the psychometric properties of the revisions made to the ARSMA-II indicated both scores had high internal reliability and consistency among the mothers included in this study (Cronbach's $\alpha$=0.91 for the maternal acculturation to the US culture subscale score (MA-US), and Cronbach's $\alpha$=0.87 for the maternal acculturation to the Mexican culture subscale score (MA-MX)).

## Anthropometric Outcomes

### Salivary Telomere Measurements

Child saliva was collected with the Oragene ™ DNA sample self- collection kit (OGR-500, DNA Self-Collection Kit, Genotek, Ottawa, Ontario, Canada). Samples from Mexico were shipped to the University of Illinois at Urbana-Champaign at room temperature using a commercial carrier. All samples were centrally stored at room temperature in the laboratory of Dr. Teran-Garcia at the University of Illinois at Urbana-Champaign where DNA extractions were performed. DNA extractions were done from 500-µL saliva aliquots using prepIT-L2P (DNA Genotek, ON, Canada) and following manufacturer instructions for ethanol precipitation. Telomere length measurements were measured in all children from genomic DNA by the laboratory of Dr. Blackburn at the University of California, San Francisco.

The telomere length measurement assay was adapted from the published original method by Cawthon [33, 34]. To control for inter-assay variability, control DNA samples (n=8) were included in each run. The average normalizing factor from all 8 samples was used to correct the participant DNA samples, and were used to calculate the final telomeric product to a single copy gene product (T/S) ratio. Telomere lengths are expressed using this T/S ratio. The T/S ratio for each sample was measured twice. If the coefficient of variation exceeded 7%, the samples were retested. The average coefficient of variation between the duplicate T/S value and the initial value for this study was 2.3%.

### Body Composition Measurements

Height and body composition were measured with children dressed in light clothing and barefoot. Standing height was measured to the nearest 0.1 cm, using a portable stadiometer (Seca 213, Hamburg, Germany). Body composition was examined using an eight points of tactile electrodes impedance analyzer with contact at the hands and feet (InBody 230™, BioSpace, Seoul, Korea). Children were asked to stand still on the device pretending to be in a spaceship while it measured body weight, body fat mass, and fat-free mass in kg., and calculated the raw BMI, and proportion of adiposity in weight, or percentage of body fat (PBF). Child measurements of weight, height and age were used to calculate the sex specific BMI-P based on the CDC's 2000 BMI-for-age growth charts. CDC criteria was used for classifications of overweight (at or above the sex-specific 85$^{th}$ BMI-P, but less than the 95$^{th}$), and obesity (at or above the sex-specific 95$^{th}$ BMI-P) [35].

**Covariates**

Mothers were asked their child's age in years and sex. Age was entered into all models as a continuous variable, and sex and country of residence were included as a dichotomous variables.

**Data analyses**

Descriptive characteristics of the children were calculated as frequencies, and percentage for categorical variables, and means and standard deviations for continuous. Descriptive characteristics, and family nutrition and physical activity behaviors examined in the FNPA are introduced for the whole sample, and by country, for each subsample. Differences in demographic characteristics, anthropometric measurements, and health behaviors between the subsample from Mexico and the US were compared using chi-square tests for categorical data, and independent sample t-test, for continuous variables. Levene's tests were conducted to examine if the homogeneity of variances was met in the data, and results for the t-tests were reported accordingly.

Multiple linear regression tests were used to test the associations between each behavioral construct from the FNPA and the moderation effect with MA-US, and MA-MX with three outcomes: (1) salivary telomere lengths, (2) body fat mass, and (3) sex specific BMI-P. Child age, and child sex were included as covariates in model A. Although differences by country were consider a covariate, we examine the contribution from this variable separately in Model B to be able to recognize effects attributable to sample differences. Main effects of maternal acculturation were tested first in Model C, followed by assessment of interactions, tested in models D-1 to D-10. Tests follow the order of the 10 factors examined in the FNPA: (1) Family meals; (2) Family eating practices; (3) Food choices; (4) Beverage choices; (5) Food restrictions, or uses of food to reward good behavior; (6) Family regulations of screen time; (7) Healthy environment; (8) Family support for physical activity; (9) Child physical activity, and (10) Family sleep routine habits. The influences from the MA-US, and MA-MX were examined in separate models following the same order, and presented in separate tables.

We explored significant interactions with tests of simple slopes in which the full spectrum of scores from the health behaviors (1 to 4) were used to plot in "x" their relationship with biological outcomes "y" as a function of the lowest maternal acculturation possible (ARSMA-II score =1), a middle or moderate maternal acculturation score (ARSMA-II score =3), and the highest acculturation possible (ARSMA-II score =5). Descriptive and regression analyses were conducted in IBM SPSS version 24 (Statistical Package for the Social Sciences, version 24.0, SPSS Inc., Chicago, IL, US), and analyses of the simple slopes were conducted in R Rweb1.03 (The R Foundation for Statistical Computing, RC Team 2013, Vienna, Austria) [36].

## Results

The descriptive characteristics of the child participants and their mothers with comparisons by country of residence are shown in Table 4.1. Of the 108 children recruited, 49% were boys and 105 had telomere measurements. One third of the children had a sex specific BMI-P > $85^{th}$

percentile (33.33%). Of the children who had overweight or obesity, 36.70% of were recruited in the US, and 32% were recruited in Mexico, but categorical differences in weight status were not statistically different. Children recruited in the US were significantly older ($p < 0.01$); and had a higher mean sex specific BMI-P ($p = 0.04$), than their counterparts in Mexico. Still, there were no differences in salivary telomere lengths, body fat mass, and weight status between children recruited in Mexico, and the US. Acculturation results showed that mothers living in the US had higher MA-US ($p < 0.01$), and mothers living in Mexico reported higher MA-MX ($p = 0.03$).

**Differences in health behaviors by country of residence**

Table 4.2. shows how the distributions of the 10 family environmental and behavioral factors examined compare by country of residence. Although children recruited in Mexico had slightly lower prevalence of obesity, mothers or children recruited in the US reported higher prevalence of healthy behaviors. Results from the t-test examining the health behaviors by country, showed that feeding habits, specifically beverage choices, and use of food as restriction or reward, were significantly different between the two countries ($p < 0.01$, and $p < 0.01$, respectively). There were also notable differences in family practices of physical activity. Compared to families in Mexico, families in the US were more likely to provide an environment that is supportive or conducive to physical activity (healthy environment, $p < 0.01$), and to actively promote physical activity in the family context ($p < 0.01$). Lastly, families in the US were significantly more likely to adhere to a bedtime routine, and allow children to sleep enough at night ($p < 0.01$).

Further analyses of responses to specific items revealed differences in beverage choices, uses of food to reward children, and promotion of physical activity within the family context (results not shown). Low intake of soda pop or sweetened beverages (<2 days per week) was reported by 83% of mothers of children recruited in the US, compared to 36.4% of mothers of children recruited in

Mexico ($p < 0.01$). Families in the US were also less likely to use candy, ice cream or other foods as a reward for good behavior, 83% of mothers in the US reported doing this less than 2 days per week, compared to 57% of families in Mexico. Differences in healthy environment were driven by the low provision of opportunities for physical activity reported by mothers in the US. 70% of mothers recruited in the US, and 49% of mothers recruited in Mexico reported family opportunities for physical activity were provided less than 2 days per week. Still, mothers in the US reported children doing physical activity with at least one other family member more frequently than mothers in Mexico ($p < 0.01$).

Table 4.3 shows the results for the analyses of the influences of MA-US and 3b the associations for the MA-MX for the same analyses with to salivary telomere lengths, fat mass, and sex specific BMI-P as outcomes, controlling for age, sex, and country of residence.

The direct effects of age were associated with child fat mass ($b = 1.13$, $p < 0.01$), and child sex specific BMI-P ($b = 9.29$, $p < 0.05$). No gender differences were detected. Despite the observed differences by country of residence, the direct effects in the linear regression analyses show country differences were not significantly associated with child salivary telomere lengths, body fat mass, or sex specific BMI-P.

**Influence from maternal acculturation to the US**

Higher MA-US was not associated with child salivary telomere measurements ($b = 0.03$ $p = 0.57$), but was significantly associated with increases in child fat mass ($b = 1.10$, $p < 0.01$), and child sex specific BMI-P ($b = 8.61$, $p < 0.05$). Models show that few family environmental and behavioral factors were significant predictors of the biological outcomes examined after corrections for age, gender, country of residence, and MA-US. Direct effects of family sleep routine habits were associated with shorter telomeres ($b = -0.17$, $p = 0.03$). Direct effects of beverage choices were associated with higher fat mass (b =0.97, p =0.03), and higher family and child physical activities were associated with higher child sex specific BMI-P (b =13.65, p =0.02; and (b =11.95, p =0.03, respectively). MA-US influenced the relationship between family eating practices, with salivary telomere lengths (b =-0.21, p =0.04). There was also an interaction between family sleep routine with child fat mass (b =1.35, p =0.02).

Tests of the simple slopes indicated that there were no significant effects for children born to mothers with moderate to the lowest acculturation to the US culture. Among children born to Mexican mothers with the highest acculturation to the US, healthier family eating practices were associated with shorter telomere lengths (Figure 4.1; b =-0.63, SE =0.31 p <0.05), and adhering to healthier family sleep routine was associated with increases in fat mass (Figure 4.2; b =4.32, SE =1.90 p <0.05).

**Influence from maternal acculturation to the Mexican culture**

Results from Table 4.4. show that none of the family environmental and behavioral factors examined were associated with salivary telomere lengths after controlling for age, gender, country of residence, and MA-MX. There were three interactions showing the influence of MA-MX on the associations between health behaviors with child fat mass, and sex specific BMI-P. MA-MX influenced the association of regulations for screen time with child fat mass (b =2.84, p =0.04), and family sleep routine adherence with child fat mass (b =2.45, p =0.05). MA-MX also influenced the interaction between healthy family environments with sex specific BMI-P (b =24.83, p=0.03). Test of the simple slopes for these interactions show no effects on child fat mass for children born to mothers with the highest MA-MX. Instead, we found a protective effect for child fat mass, protecting children with mother who had low to moderate MA-MX. Limiting children's screen time more often was associated with reductions in child fat mass for children born to mothers with moderate MA-MX (Figure 4.3; b =-10.85, SE =5.25 p =0.042), and low MA-MX (Figure 4.3; b =-5.17, SE =2.02 p =0.047). Similarly, the interaction between MA-MX, with the association of family sleep routines with child fat mass, was only significant among children born to mothers with low and moderate MA-MX (Figure 4.4; b =-9.11, SE =4.38 p =0.041; and b =-4.21, SE =2.02 p =0.040, respectively).

Results from the simple slopes exploring the interaction of MA-MX with the association of family healthy environments with sex specific BMI-P showed the direction of the associations were different if mothers had high or low to moderate MA-MX. For children with mothers who reported low and moderate MA-MX, healthier environments were associated with lower child sex specific BMI-P (Figure 4.5; *b*=-88.28, SE=4.57 p=0.033; *b*=-38.63, SE=19.01 p=0.046, for low and moderate MA-MX, respectively). In contrast, among mothers with high MX-MX, healthier family environments as examined by the FNPA, were associated with increases in their child's sex specific BMI-P (Figure 4.5; *b*=11.03, SE=2.09, p=0.034).

**Discussion**

Our study found that associations of family health environments and behaviors with children's telomere lengths, adiposity, and weight status, vary by mothers' level of acculturation to the US and to the Mexican cultures. Findings suggest that as a consequence of remote acculturation, differences observed by maternal acculturation to the US and Mexican cultures were independent of country of residence. In children born to mother's higher acculturation to the US, having healthier family eating practices, and adhering to a sleep routine more often, were associated to lower telomere lengths (β =-2.39, p =0.04; β =-0.34, p =0.03). For children with mothers who have between low and moderate acculturation to Mexico, having controlled screen exposure, and adhering to sleep routine more often, were associated with lower fat mass . The interaction between family healthy environments with children sex specific BMI-P show the effects on sex specific BMI-P vary by mothers' acculturation to the Mexican culture (see Figure 4.5). Among mothers with low to moderate acculturation to the Mexican culture, providing a healthier environment – that is, having lower access to a screen in the child's bedroom, and opportunities to be active with the family more often, was associated with decreases in child's sex specific BMI-P. In contrast, for children of mothers with the highest maternal acculturation to the Mexican culture, sex specific BMI-P increased with higher frequency of access to healthy environments.

**Family eating practices**

In the FNPA, healthier family eating practices are examined by asking mothers how often children eat snacks while watching TV, and fast-food intake [28]. Further examinations into the two items used to measure family eating practices in our study revealed this association is mostly influenced by the interaction between child frequency of snack intake and telomere lengths. The influence of child frequency of snack intake on telomere lengths differed by level of maternal acculturation. Simple-intercepts of the interaction of maternal acculturation to the US with snack intake and telomere lengths suggested confounding effects could be driving the relationship (Results not shown). Children of mothers with the highest acculturation to the US, whose mothers reported their child never eats snacks while watching TV had the shortest telomere lengths intercepts (b =1.14, compared to b =1.60 for moderate MA-US, and 2.07 for high MA-US). The simple slope showed that for these children, there was a marginally significant increase in telomere lengths associated with higher snack intake (b =0.27, SE =0.14, p =0.06). Previous studies have observed that children snack intake is associated to restrictive parental feeding, and availability of snacks in the home [37]. Given the socioeconomic in our sample, it is possible that the interaction between maternal acculturation to the US, snack intake, and telomere lengths may explained by lack of snacks at home due to food insecurity [38]. Although the effects of food insecurity on telomere lengths in childhood are not conclusive, previous studies have observed experiences of food insecurity lead to shorter telomere lengths [38, 39]. The second item used to measure family eating practices was intake of fast food, which was not associated with children's telomere lengths or maternal acculturation to the US ($p > 0.05$).

**Family sleep habits (adhering to a sleep routine, and length of sleep)**

Studies that examined the associations between sleep and obesity in childhood have yield conflicting results [29, 40]. In our sample, we found that adhering to a family sleep routine more often, and longer sleep duration were associated with higher fat mass among children of mothers with the highest acculturation to the US. In contrast, for children of mothers with low and moderate acculturation to Mexico, fat mass decreased when children follow a sleep routine and slept longer (see Figure 1b). Previous studies that used the same instrument to assess sleep behaviors (FNPA) found that among children ages 5-18 years old, lower frequency of bedtime routines, and shorter sleep duration were more common among youth with severe obesity, compared to overweight children [29]. These findings are consistent with the associations we identify for the influence of low and moderate maternal acculturation to Mexico, but contradictory with our results for the influence of highest maternal acculturation to the US on children's fat mass. The limited number of mothers with high acculturation scores in our sample, and low statistical power may have contribute to this conflicting finding.

### Family screen time monitoring

The relationship between screen time and obesity is well-established. Randomized control trials have demonstrated cause and effect by achieving weight loss after limiting children's screen time [41]. Previous studies that used the FNPA, identify differences in screen time monitoring among children with overweight and severe obesity, and found that reductions in screen time exposure were associated with lower sex-specific child BMI for age Z-scores [29, 42]. In our study, among children with low or moderate acculturation to the Mexican culture, higher parental screen monitoring was associated with reductions in fat mass. These findings about screen time behaviors extend previous findings among US Latino children that suggest there may be a cultural influence in the association between screen time and obesity. A previous study of 314 parents of 0 to 5 year old children showed that child screen time exposure among low-income Latino families was associated with the number of televisions at home, and the television habits parents model to their children [43]. Among Latino parents in the US, it has been documented that parent's believe that TV-watching is important for their young child's visual and cognitive development [44]. Our study suggests that support TV-viewing in early childhood are stronger among mothers with lower acculturation to the Mexican culture.

### Family healthy environment (sedentary behaviors)

Although the FNPA screening tool examines the overall family environment, a specific construct labeled 'healthy environment' is included to account for access to screens or monitors in child's bedroom, and family opportunities for physical activity [28]. This means that the assessment of family healthy environments focuses on the extent to which families discourage sedentary behaviors among children. Sedentary behaviors are particularly concerning among Mexican populations. In the US, Mexicans are the most sedentary group across all age-groups [45]. In our study we found that for children of mothers with low or moderate acculturation to the Mexican culture, providing a healthier environment more often was associated with significant reductions on child sex specific BMI-P. In contrast, for children with mothers who have high acculturation to the Mexican culture, healthier environments were associated with increases in sex specific BMI-P. In the interaction plot, children with mothers who have low or moderate acculturation to the Mexican culture began at a higher sex specific BMI-P. This means, that children of mothers with low acculturation to the Mexican culture were at increased risks for obesity. In contrast, children of mothers with high acculturation to the Mexican culture began at a lower sex specific BMI-P, and were at risk for underweight. Taken together, the simple slopes and simple-intercepts illustrating this relationship (Figure 3) demonstrate that discouraging sedentary behaviors yields a healthy sex specific BMI-P range for all children.

Providing health recommendations is a public health challenge to countries like Mexico that are facing the double-burden of malnutrition - where children are both at risk for undernutrition and obesity [46]. Our findings suggest that limiting sedentary behaviors in children leads to healthier growth trajectories for children who are at risk for obesity, or underweight. Furthermore, in the context of parent-child relationship, previous studies have documented that the influence of parents modeling of sedentary behaviors is stronger than modeling of physical activity [47]. At the same time, previous studies have documented that increases in parents' physical activity are associated with greater child physical activity [48]. Thus, the recommendations for Mexican mothers interested in limiting their children's sedentary behaviors, should be to achieve this by modeling physical activity themselves, and providing opportunities for the whole family to be active.

### Strengths and Limitations

Our study is unique in its focus on low-income Mexican young children living in Mexico and the US. Strengths of this study include the administration of FNPA screening tool, and the multidimensional assessment of acculturation to the US and Mexican cultures (ARMSA-II) in both English and Spanish with a sample of Mexican mothers living in both countries, the assessments of salivary telomere lengths, and the use of objective measurements of body composition rather than relying in parental self-report. Nonetheless, study results should be interpret with caution. Our sample was not randomized, nor nationally representative, as a result, findings are specific for the study participants. We relied on mother self-reported subjective assessments of their family environment and health behaviors. Remote exposure to the US culture varies by socio-economic status, as wealthier Mexicans living in Mexico often have access to travel to the US, and bilingual education. Future studies should examine how social determinants of health may challenge some of the associations identified between environmental and behavioral factors with child health outcomes. Also, health behaviors could yield different health outcomes for families experiencing food insecurity and social adversity, especially in places that continue to struggle with undernutrition, like different regions in Mexico.

### Conclusion

Our study show that maternal cultural affinities to the US and Mexican cultures influence children's health by moderating the relationship between health behaviors and children's health outcomes. Maternal cultural influences on children's health were documented from the child telomere lengths to their adiposity accumulation and weight status, with implications for childhood obesity risks for young children born to Mexican mothers living in Mexico and the US. We identify specific behaviors that should be intervention targets to reduce accumulation of excessive adiposity among young children of Mexican mothers in Mexico and the US. We suggest to particularly focus childhood obesity prevention efforts on Mexican mothers with higher acculturation to the US, and low or moderate acculturation to Mexico. Future studies should examine the effectiveness in reducing excessive adiposity accumulation among young children by delivering culturally-sensitive messages that (1) highlight the importance of adhering to a family sleep routine, and sufficient night-time sleep duration; (2) refute beliefs about the value of TV for young children; and (3) encourage mothers to limit sedentary behaviors and model physical activity to their young children.

## Tables and Figures

**Table 4.1.** Mother and child characteristics by country of residence

| Characteristics | All (n=108) | Mexico (n=78) (%, (n)/ *m* ±sd | US (n=30) |
|---|---|---|---|
| **Child Characteristics** | | | |
| Children's age** | 4.58 ±0.73 | 4.40 ±0.54 | 5.1 ±0.88 |
| 4 years old | 55.6 (60) | 64.1 (50) | 33.3 (10) |
| 5 years old | 30.6 (33) | 33.3 (26) | 7 (23.3) |
| 6 years old | 13.9 (15) | 2.6 (2) | 13 (43.3) |
| Children's gender (Male) | 49.1 (53) | 46.2 (36) | 56.7 (17) |
| Children's salivary telomere lengths | 1.69 ±0.28 | 1.70 ±0.30 | 1.36 ±0.23 |
| Telomere length by age group | | | |
| 4 years old | 1.71 ±0.29 | 1.71 ±0.30 | 1.70 ±0.23 |
| 5 years old | 1.68 ±0.28 | 1.69 ±0.29 | 1.64 ±0.27 |
| 6 years old | 1.62 ±0.28 | 1.44 ±0.43 | 1.66 ±0.26 |
| Children's Body Fat Mass | 5.5 ±2.70 | 5.35 ± 2.64 | 5.92 ± 2.87 |
| Children's sex specific BMI-P*+ | 63.9 ±30.36 | 60.6 ±32.00 | 72.5 ± 23.90 |
| Children's Weight Status | | | |
| Normal (5th to 84.9th BMI-P) | 66.7 (72) | 67.9 (53) | 63.3 (19) |
| Overweight (>85th BMI-P) | 13.9 (15) | 12.8 (10) | 16.7 (5) |
| Obese (>95th BMI-P) | 19.4 (21) | 19.2 (15) | 20.0 (6) |
| **Mother Characteristics** | | | |
| Mother's age (range 19 -55) + | 30 ±6.53 | 29 ±7.00 | 32 ±5.00 |
| Mother's BMI (kg/m$^2$) | 27.52 ± 4.53 | 16.38 ±2.22 | 17.12 ±2.22 |
| Mother's Weight Status | | | |
| Normal | 25.9 (28) | 33.3 (26) | 6.7 (2) |
| Overweight | 25.9 (28) | 24.4 (19) | 30.0 (9) |
| Obese | 41.7 (45) | 37.2 (29) | 53.3 (16) |
| Acculturation (ARSMA-II) | | | |
| Mother's acculturation to the US culture (MA-US)** + | 2.17 ±1.07 | 1.69 ±.63 | 3.07 ±1.15 |
| Mother's acculturation to the US culture range (MA-US) | 1.00 to 5.00 | 1.00 to 4.00 | 1.55 to 5.00 |
| Mother's acculturation to the Mexican culture (MA-MX)* + | 4.67 ±0.56 | 4.79 ±0.33 | 4.37 ±0.86 |
| Mother's acculturation to the Mexican culture range (MA-MX) | 1.42 to 5.00 | 3.75 to 5.00 | 1.42 to 5.00 |

*p <0.05; ** p <0.001;
+p-value equal variances not assume

**Table 4.2.** Distribution and comparison by two independent sample t-tests of family environmental and behavioral constructs (FNPA) by country

| **Family Health Behaviors** | **All** *m ± sd* | **Mexico** *m ± sd* | **US** *m ± sd* | *p-value* |
|---|---|---|---|---|
| Family Meals | 3.58 ± 0.56 | 3.57 ± 0.55 | 3.59 ± 1.61 | 0.91 |
| Family Eating Practices | 2.80 ± 0.54 | 2.74 ± 0.55 | 2.98 ± 1.49 | 0.04 |
| Food Choices | 3.40 ± 0.42 | 3.43 ± 0.40 | 3.38 ± 1.48 | 0.60 |
| Beverage Choices+ | 2.58 ± 0.81 | 2.34 ± 0.77 | 3.19 ± 1.54 | <0.01 |
| Restriction/Reward | 3.01 ± 0.65 | 2.89 ± 0.64 | 3.31 ± 1.60 | <0.01 |
| Screen Time | 3.00 ± 0.67 | 3.05 ± 0.69 | 2.85 ± 1.66 | 0.20 |
| Healthy Environment | 2.54 ± 0.74 | 2.42 ± 0.73 | 2.87 ± 1.71 | <0.01 |
| Family Activity | 2.85 ± 0.80 | 2.71 ± 0.78 | 3.31 ± 1.75 | <0.01 |
| Child Activity | 2.57 ± 0.63 | 2.60 ± 0.67 | 2.48 ± 1.53 | 0.40 |
| Family Schedule/Sleep Routine+ | 2.72 ± 0.62 | 2.60 ± 0.64 | 2.96 ± 1.48 | <0.01 |

+*p*-value equal variances not assume

**Table 4.3.** Influence of maternal acculturation to the US culture on the associations between family environmental and behavioral factors with obesity-related biological outcomes

| Model | Independent Variables | Salivary Telomere Lengths | | |
|---|---|---|---|---|
| | | b | 95% CI | $R^2$ |
| C | Maternal acculturation to the US (MA-US) | 0.03 | (-.07, .12) | 0.05 |
| D.1 | Family Meals | 0.07 | (-.07, .20) | 0.07 |
| E.1 | Family Meals x MA-US | 0.16 | (-.01, .33) | 0.13 |
| D.2 | Family Eating Practices | -0.03 | (-.20, .15) | 0.05 |
| E.2 | Family Eating Practices x MA-US | -0.21* | (-.40, .01) | 0.12 |
| D.3 | Food Choices | 0.06 | (-.13, .24) | 0.06 |
| E.3 | Food Choices x MA-US | 0.00 | (-.15, .15) | 0.06 |
| D.4 | Beverage Choices | 0.04 | (-.08, .16) | 0.06 |
| E.4 | Beverage Choices x MA-US | -0.01 | (-.09, .08) | 0.06 |
| D.5 | Restriction and Reward | 0.03 | (-.12, .18) | 0.05 |
| E.5 | Restriction and Reward x MA-US | 0.07 | (-.06, .21) | 0.07 |
| D.6 | Screen Time | 0.02 | (-.10, .14) | 0.05 |
| E.6 | Screen Time x MA-US | -0.02 | (-.15, .12) | 0.05 |
| D.7 | Healthy Environment | -0.09 | (-.21, .041) | 0.07 |
| E.7 | Healthy Environment x MA-US | -0.02 | (-.16, .12) | 0.07 |
| D.8 | Family Activity | -0.11 | (-.24, .02) | 0.10 |
| E.8 | Family Activity x MA-US | 0.00 | (-.12, .11) | 0.10 |
| D.9 | Child Activity | -0.01 | (-.14, .12) | 0.04 |
| E.9 | Child Activity x MA-US | -0.10 | (-.27, .06) | 0.07 |
| D.10 | Family Sleep Routine | -0.17* | (-.33, -.01) | 0.15 |
| E.10 | Family Sleep Routine x MA-US | -0.08 | (-.23, .07) | 0.17 |

*$p < 0.05$

**Table 4.3. (cont.)**

| Model | Independent Variables | Body Fat Mass | | | BMI-for-age-Percentile | | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | $R^2$ | b | 95% CI | $R^2$ |
| C | MA-US | 1.10 | (.39, 1.81) | 0.25 | 8.61 | (.11, 17.11) | 0.13 |
| D.1 | Family Meals | 0.70 | (-.30, 1.71) | 0.28 | 5.16 | (-7.15, 17.47) | 0.14 |
| E.1 | Family Meals x MA-US | -0.79 | (-2.11, .53) | 0.30 | -11.95 | (-27.72, 3.83) | 0.18 |
| D.2 | Family Eating Practices | 0.00 | (-1.34, 1.34) | 0.25 | 6.48 | (-9.46, 22.41) | 0.06 |
| E.2 | Family Eating Practices x MA-US | -0.23 | (-1.80, 1.34) | 0.25 | 8.61 | (-9.88, 27.11) | 0.08 |
| D.3 | Food Choices | 0.74 | (-.63, 2.12) | 0.27 | 9.44 | (-6.98, 25.86) | 0.15 |
| E.3 | Food Choices x MA-US | 0.90 | (-.21, 2.01) | 0.30 | 2.40 | (-11.18, 15.98) | 0.16 |
| D.4 | Beverage Choices | 0.97* | (.12, 1.82) | 0.32 | 6.85 | (-3.62, 17.32) | 0.16 |
| E.4 | Beverage Choices x MA-US | 0.21 | (-.392, .82) | 0.32 | -0.82 | (-8.31, 6.67) | 0.16 |
| D.5 | Restriction and Reward | 0.35 | (-.77, 1.46) | 0.26 | -3.92 | (-16.74, 8.89) | 0.16 |
| E.5 | Restriction and Reward x MA-US | 0.96 | (-.06, 1.97) | 0.31 | -0.04 | (-12.10, 12.03) | 0.16 |
| D.6 | Screen Time | 0.17 | (-.74, 1.07) | 0.30 | 3.48 | (-7.27, 14.22) | 0.17 |
| E.6 | Screen Time x MA-US | 0.35 | (-.65, 1.35) | 0.31 | -3.41 | (-15.27, 8.44) | 0.17 |
| D.7 | Healthy Environment | 0.45 | (-.51, 1.40) | 0.31 | 9.68 | (-1.32, 20.68) | 0.21 |
| E.7 | Healthy Environment x MA-US | 0.97 | (-.05, 1.98) | 0.35 | 4.44 | (-7.53, 16.42) | 0.22 |
| D.8 | Family Activity | 0.59 | (-.37, 1.55) | 0.32 | 13.65* | (2.69, 24.61) | 0.25 |
| E.8 | Family Activity x MA-US | 0.83 | (-.01, 1.66) | 0.37 | 1.48 | (-8.41, 11.38) | 0.25 |
| D.9 | Child Activity | 0.10 | (-.86, 1.05) | 0.29 | 11.95* | (1.19, 22.70) | 0.24 |
| E.9 | Child Activity x MA-US | -0.33 | (-1.59, .92) | 0.30 | 2.85 | (-11.28, 16.98) | 0.24 |
| D.10 | Family Sleep Routine | 0.05 | (-1.19, 1.28) | 0.24 | 10.28 | (-4.00, 24.56) | 0.20 |
| E.10 | Family Sleep Routine x MA-US | 1.35* | (.20, 2.50) | 0.31 | 12.78 | (-.75, 26.32) | 0.26 |

*p <0.05

**Table 4.4.** Influence of maternal acculturation to the Mexican culture on the associations between family environmental and behavioral factors with obesity-related biological outcomes

| Model | Independent Variables | Salivary Telomere Lengths | | |
|---|---|---|---|---|
| | | b | 95% CI | $R^2$ |
| C | Maternal acculturation to the Mexico (MA-MX) | 0.05 | (-.07, .17) | 0.04 |
| D.1 | Family Meals | 0.08 | (-.03, .19) | 0.07 |
| E.1 | Family Meals x MA-MX | -0.17 | (-.48, .14) | 0.08 |
| D.2 | Family Eating Practices | 0.01 | (-.44, .14) | 0.04 |
| E.2 | Family Eating Practices x MA-MX | 0.00 | (-.27, .27) | 0.04 |
| D.3 | Food Choices | 0.02 | (-.13, .17) | 0.05 |
| E.3 | Food Choices MA-MX | -0.05 | (-.29, .20) | 0.05 |
| D.4 | Beverage Choices | -0.03 | (-.12, .06) | 0.05 |
| E.4 | Beverage Choices x MA-MX | 0.03 | (-.10, .16) | 0.05 |
| D.5 | Restriction and Reward | 0.03 | (.07, .14) | 0.04 |
| E.5 | Restriction and Reward x MA-MX | 0.07 | (-.11, .25) | 0.05 |
| D.6 | Screen Time | 0.03 | (-.07, .13) | 0.03 |
| E.6 | Screen Time x MA-MX | 0.11 | (-.22, .43) | 0.04 |
| D.7 | Healthy Environment | -0.03 | (-.12, .067) | 0.03 |
| E.7 | Healthy Environment x MA-MX | -0.15 | (-.40, .09) | 0.05 |
| D.8 | Family Activity | -0.02 | (-.10, .07) | 0.03 |
| E.8 | Family Activity x MA-MX | -0.03 | (-.22, .17) | 0.03 |
| D.9 | Child Activity | 0.04 | (-.07, .14) | 0.03 |
| E.9 | Child Activity x MA-MX | -0.13 | (-.36, .10) | 0.05 |
| D.10 | Family Sleep Routine | 0.00 | (-.12, .12) | 0.03 |
| E.10 | Family Sleep Routine x MA-MX | -0.02 | (-.30, .26) | 0.03 |

*p <0.05

**Table 4.4. (cont.)**

| Model | Independent Variables | Body Fat Mass | | | BMI-for-age-Percentile | | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | $R^2$ | b | 95% CI | $R^2$ |
| C | MA-MX | -0.49 | (-1.90, 0.93) | 0.09 | 2.22 | (-15.75, 21.75) | 0.05 |
| D.1 | Family Meals | -0.10 | (-1.14, 0.94) | 0.09 | -0.43 | (-12.20, 11.34) | 0.05 |
| E.1 | Family Meals x MA-MX | 0.09 | (-0.88, 1.06) | 0.09 | 1.17 | (-9.79, 12.12) | 0.05 |
| D.2 | Family Eating Practices | 1.88 | (-0.86, 4.62) | 0.11 | 14.53 | (-16.69, 45.74) | 0.06 |
| E.2 | Family Eating Practices x MA-MX | 0.26 | (-.80, 1.31) | 0.11 | 4.14 | (-7.49, 15.76) | 0.06 |
| D.3 | Food Choices | 1.93 | (-.38, 4.24) | 0.13 | 15.32 | (-10.30, 40.94) | 0.08 |
| E.3 | Food Choices MA-MX | 0.33 | (-.96, 1.61) | 0.10 | 0.40 | (-13.80, 14.59) | 0.05 |
| D.4 | Beverage Choices | 1.08 | (-1.02, 3.18) | 0.12 | 9.09 | (-14.22, 32.39) | 0.06 |
| E.4 | Beverage Choices x MA-MX | 0.43 | (-.32, 1.19) | 0.11 | 2.86 | (-5.74, 11.45) | 0.05 |
| D.5 | Restriction and Reward | 0.61 | (-.52, 1.73) | 0.12 | 7.11 | (-5.63, 19.84) | 0.06 |
| E.5 | Restriction and Reward x MA-MX | -0.26 | (-1.14, .62) | 0.10 | -0.89 | (-18.45, .68) | 0.10 |
| D.6 | Screen Time | 0.46 | (-1.09, 2.02) | 0.11 | 11.70 | (-5.08, 28.48) | 0.12 |
| E.6 | Screen Time x MA-MX | 0.11 | (-.74, .96) | 0.13 | 2.57 | (-7.02, 12.16) | 0.07 |

*p <0.05

**Table 4.4. (cont.)**

| Model | Independent Variables | Body Fat Mass | | | BMI-for-age-Percentile | | |
|---|---|---|---|---|---|---|---|
| | | b | 95% CI | $R^2$ | b | 95% CI | $R^2$ |
| D.7 | Healthy Environment | 2.84* | (.14, 5.54) | 0.18 | 2.29 | (-29.07, 33.65) | 0.07 |
| E.7 | Healthy Environment x MA-MX | -0.04 | (-.84, .75) | 0.10 | 3.62 | (-4.86, 12.10) | 0.08 |
| D.8 | Family Activity | 1.33 | (-.76, 3.41) | 0.12 | 24.83* | (3.11, 46.54) | 0.14 |
| E.8 | Family Activity x MA-MX | 0.06 | (-.69, .81) | 0.11 | 6.62 | (-1.49, 14.73) | 0.10 |
| D.9 | Child Activity | 1.31 | (-.39, 3.01) | 0.14 | 8.83 | (-9.68, 27.34) | 0.11 |
| E.9 | Child Activity x MA-MX | -0.34 | (-1.21, .54) | 0.12 | 3.80 | (-5.89, 13.48) | 0.06 |
| D.10 | Family Sleep Routine | 0.87 | (-1.13, 2.87) | 0.13 | 10.38 | (-11.74, 32.49) | 0.07 |
| E.10 | Family Sleep Routine x MA-MX | -0.23 | (-1.26, .79) | 0.13 | -1.06 | (12.36, 10.25) | 0.06 |

*p <0.05

**Figure 4.1.** Interaction of salivary telomere lengths with family eating by maternal acculturation to the US (MA-US)

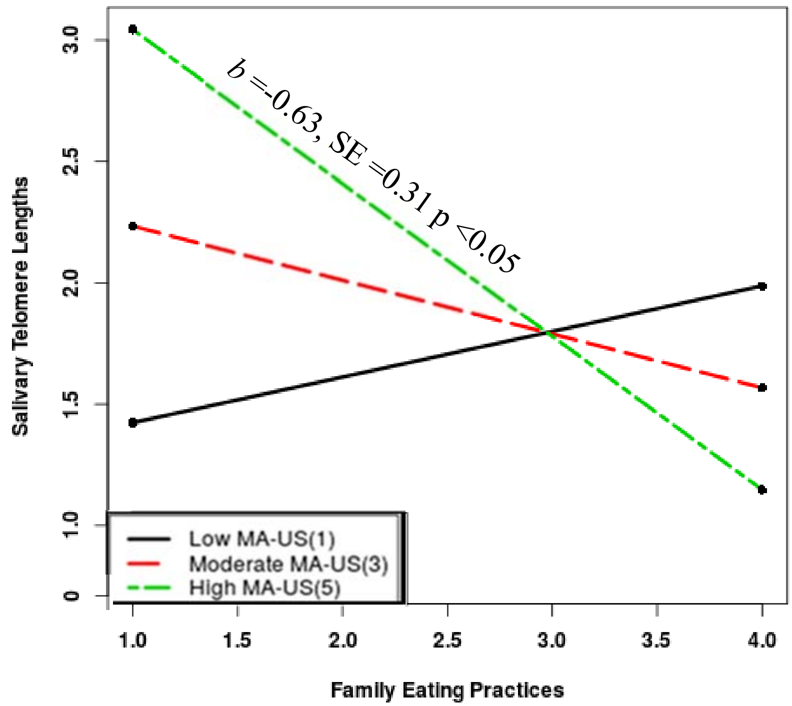
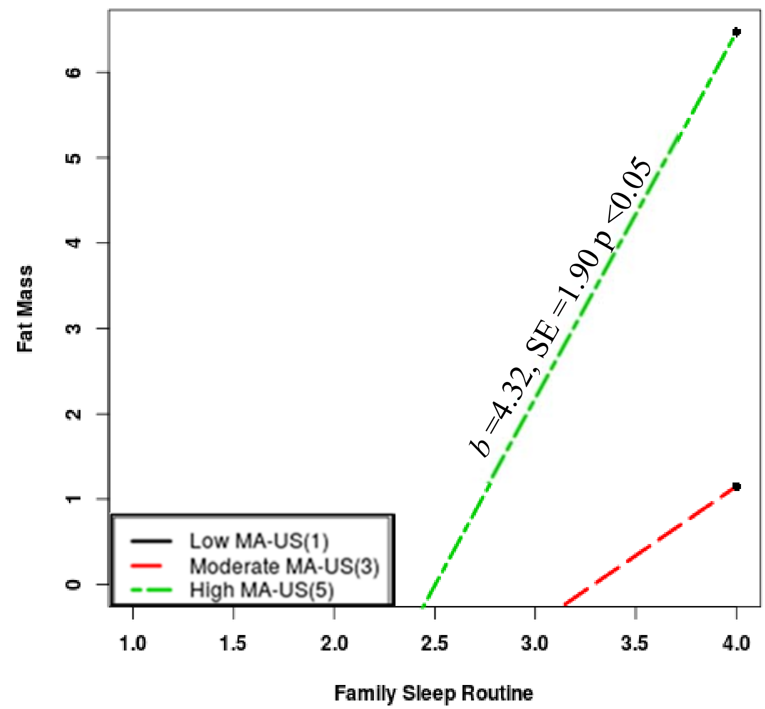


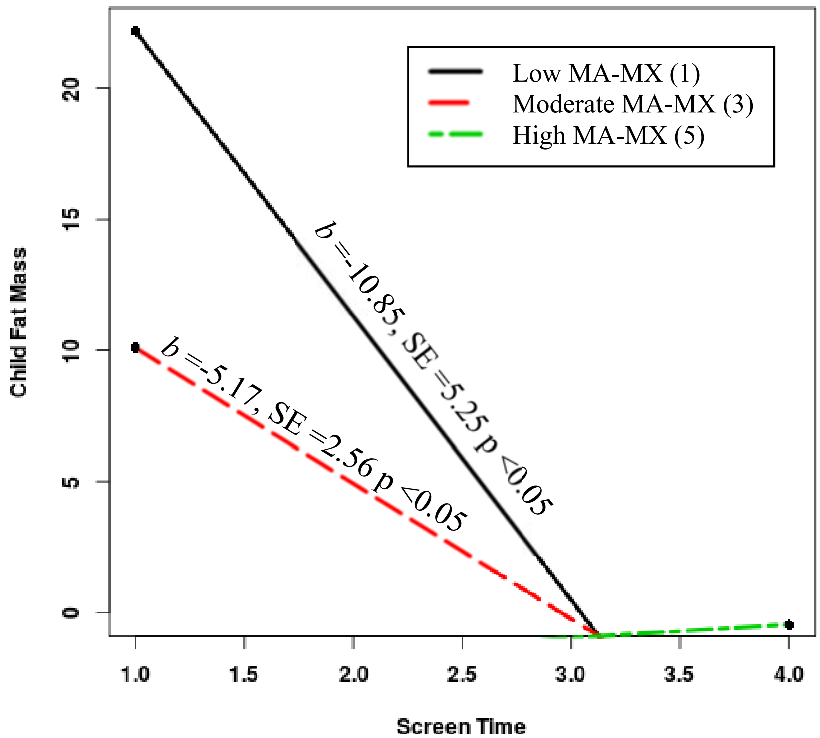

**Figure 4.2.** Interaction of fat mass with family sleep routine by maternal acculturation to the US (MA-US)




Healthier family eating practices were associated with shorter salivary telomere lengths (T/S). This negative association between salivary telomere lengths with family eating practices varied by level of MA-US. Simple slopes revealed the effect was only significant when MA-US was high (MA-US =5; $p < 0.05$). There was no statistically significant association when MA-US was moderate (MA-US=3; $p = 0.09$) or low (MA-US=1; $p = 0.16$).

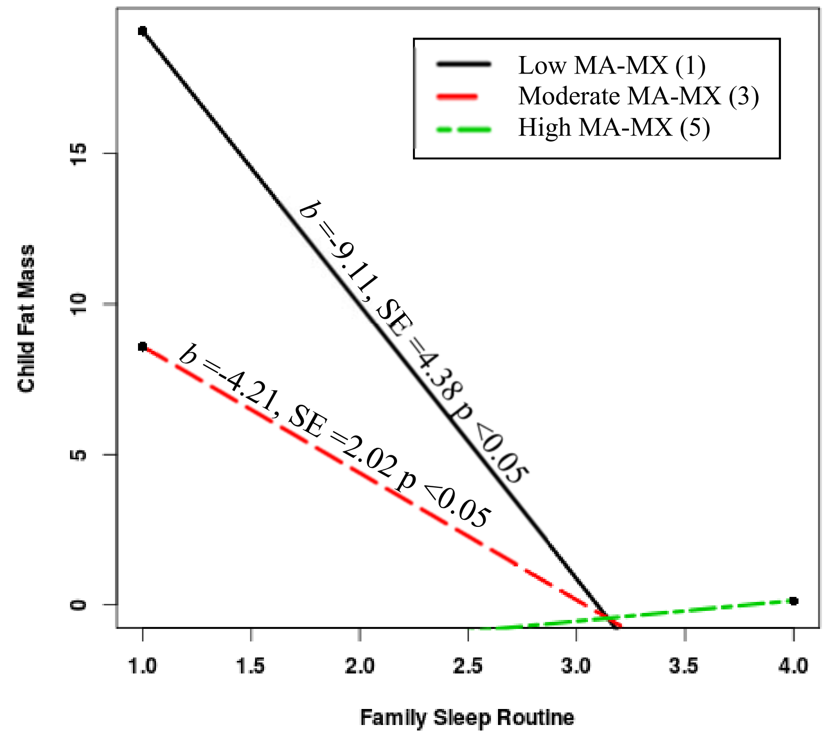
Healthier family sleep routine was associated with child fat mass (in kg), and this relationship varied by the level of maternal acculturation to the US (MA-US). Simple slopes revealed that the association was only significant when MA-US was high (MA-US=5; $p < 0.05$). There was no statistically significant association when MA-US was moderate (MA-US=3; $p = 0.07$) or low (MA-US=1; $p = 0.16$).

**Figure 4.3.** Interaction of fat mass with screen time by maternal acculturation to the Mexican culture (MA-MX)



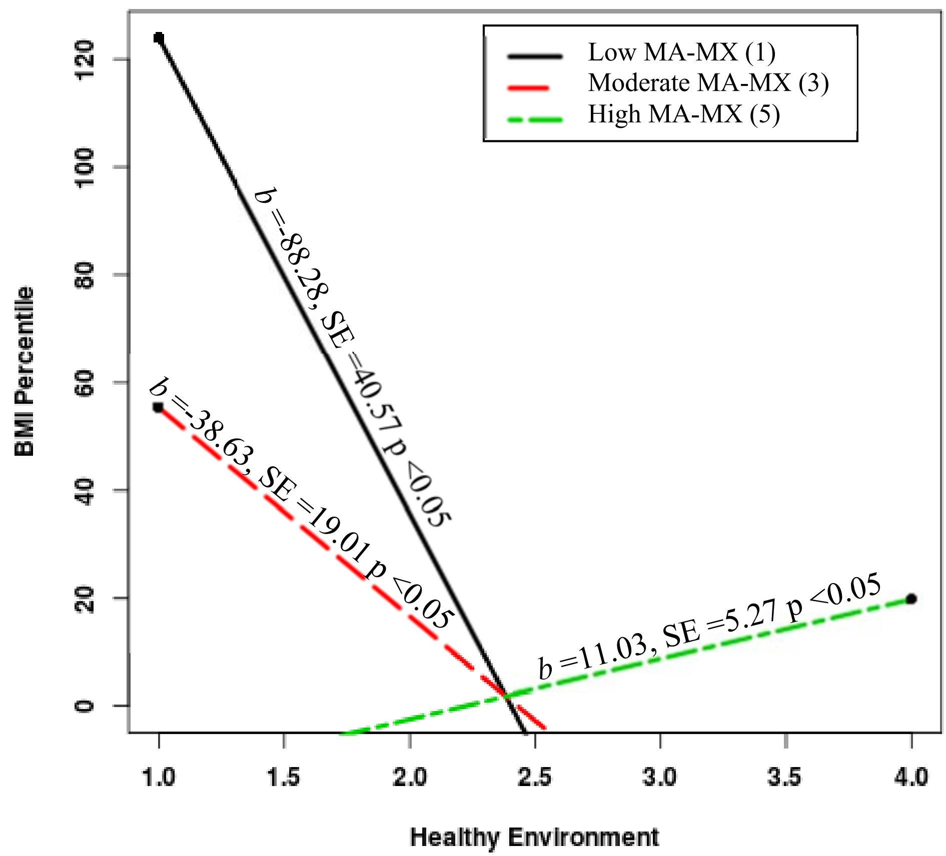

Family monitoring of screen time was associated with lower child fat mass (in kg). This negative association between fat mass with family monitoring of screen time varied by level of MA-MX. Simple slopes revealed the effect was only significant when MA-MX was low (MA-MX =1; $p < 0.05$), and moderate (MA-MX =3; $p < 0.05$). There was no statistically significant association when MA-MX was high (MA-MX=5; $p = 0.28$).

**Figure 4.4.** Interaction of fat mass with family sleep routine by maternal acculturation to the Mexican culture (MA-MX)




Following a family sleep routine more often was associated with lower child fat mass (in kg). This negative association between fat mass with family sleep routine varied by level of MA-MX. Simple slopes revealed the effect was only significant when MA-MX was low (MA-MX =1; $p < 0.05$), and moderate (MA-MX =3; $p < 0.05$). There was no statistically significant association when MA-US was high (MA-MX=5; $p = 0.32$).

**Figure 4.5.** Interaction for sex specific BMI-P for age with healthy environment by MA-MX




Providing a healthier family environment for the child more often was associated with lower sex specific BMI-P. This association between BMI-P with healthy environment varied by level of MA-MX. Simple slopes revealed the direction of the association was negative when MA-MX was low (MA-MX =1; $p < 0.05$), and moderate (MA-MX =3; $p < 0.05$). In contrast, the direction of the association was positive when MA-MX was high (MA-MX=5; $p < 0.05$).

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# CHAPTER 5: Conclusion

This dissertation reviewed different aspects of the influence of acculturation to early childhood obesity risks in an international sample of young children and their Mexican mothers. Chapter 1 introduces a brief review of the literature on obesity risk factors in early childhood. In this chapter the influence of acculturation on child and maternal health is examined in the context of the epidemiologic, demographic and nutrition transition. While the literature of acculturation is abundant, fewer studies have examined the influence of acculturation on biological measurements in childhood, and far less have explore the influences of remote acculturation to children's health. Furthermore, while many studies compare different immigrant generations, the amount of research studies investigating intergenerational associations is scarce. This dissertation focused on addressing these gaps identified in the literature.

Chapter 2, introduces the first study. In this study we analyzed the cross-sectional influences of maternal acculturation to the US and to the Mexican cultures with children's metabolic health. This study examined the associations of maternal acculturation with children's fat mass, truncal fat, lean mass, blood glucose, and lipid profile in a sample of 113 children living in Mexico and the US. We found that maternal acculturation to the US was associated with higher child fat mass for children living in the US, but not for children living in Mexico, and lower triglycerides for all children, independent of their country of residence. Higher maternal acculturation to the Mexican culture was associated with lower child lean mass, and a more adverse lipid profile, with lower HDL-cholesterol, and higher triglycerides. This is the first study to examine if the mode of cultural exposure influenced the associations between acculturation and health outcomes. Because of the transdisciplinary and international nature of this study, we believe findings will be of interest to the audience of the "International Journal of Obesity" (https://www.nature.com/ijo/), and is where we plan to submit the manuscript. This journal has documented metabolic health risk in early life among populations around the world.

In Chapter 3, we examined the intergenerational influence of maternal acculturation on the association between child-mother cellular weathering with distribution of adiposity in weight. This study proposes that acculturation is linked to exposure to psychosocial disadvantage, and introduces telomere lengths as a measurement of 'cellular weathering' attributable to acculturation and adversity. This chapter reported our results from the actor-partner-interdependence model used to test these associations. Although we found no evidence of intergenerational associations, we documented partner effects that were consistent with the previous literature on telomere lengths, and their associations with acculturation, and with obesity risks. For mother and children with high and moderate acculturation to the US, longer salivary telomere lengths were associated with a greater percentage of body fat in weight. Meanwhile, for participants with the lowest level of acculturation to the US, longer salivary telomere lengths were associated with lower adiposity in weight. No associations were recognized in relationship with maternal acculturation to the Mexican culture. Previous studies had examined the association between salivary telomere lengths and adiposity, and the influence of acculturation to salivary telomere lengths. This is the first study to explore the joint effect in the context of the child-mother dyads, with very young children. We believe the socio-ecological approach we follow to study obesity risks in an international sample makes this manuscript a good fit for the journal of "Social Science and Medicine" (https://www.journals.elsevier.com/social-science-and-medicine). This journal has published several manuscripts about the health effects of acculturation, and its readers are interested in transdisciplinary research that advance current knowledge of the cultural, and psychosocial determinants of health.

In Chapter 4, the third study focused on the differences in family environmental and behavioral factors attributed to mothers' acculturation to the US and Mexican cultures, and the corresponding child health outcomes. This study found that maternal acculturation to the US and Mexican cultures shape the associations between health behaviors and young children's obesity risks. Effects from the interaction of behavioral factors with maternal acculturation were observed from the chromosome level to their adiposity accumulation, and weight status. Notably, this study shows that country differences had no effect on the influence of maternal acculturation to children's health. Study recommendations include delivering culturally-sensitive messages via interventions to mothers with low or moderate acculturation to Mexico in Mexico and the US. In the future, it will be crucial to measure the effectiveness of addressing sleep habits, screen exposure, and reductions in sedentary behaviors with Mexican mothers of young children living in Mexico and the US, and how changes in these behaviors influence children cellular health, adiposity accumulation and weight status. The identification of specific cultural factors and family environmental and behavioral risks driving childhood obesity is an area that the journal of "Childhood Obesity" (https://www.liebertpub.com/loi/chi) focuses upon. Therefore, this manuscript will be submitted to this journal which is particularly interested in genetic, behavioral, and environmental factors associated with obesity disparities.

## Summary

Overall, study results do not conclusively support or refute the Hispanic/Latino health paradox. Instead, we found that acculturation to the US and to the Mexican culture introduce both obesity protective and risk factors that can affect children's cellular health, metabolic risks, and weight status. Together, studies provide new evidence about the influence of acculturation to the US and Mexican cultures on an international sample of child-mother dyads. Findings provide important insights about the obesity risks introduced by acculturation and remote acculturation processes to maternal and child health. These findings advance the field and recommend culturally-sensitive interventions aim to promote children's health by improving health behaviors linked to maternal acculturation.