Title
Socioeconomic disparities, unaffordable housing and obesity among low-income preschool-aged children in Los Angeles

Author
Sadegh-Nobari, Tabashir

Publication Date
2016

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA

Los Angeles

Socioeconomic disparities, unaffordable housing and obesity among low-income preschool-aged children in Los Angeles

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Public Health

by

Tabashir Zahra Sadegh-Nobari

2016

ABSTRACT OF THE DISSERTATION

Socioeconomic disparities, unaffordable housing and obesity among low-income preschool-aged children in Los Angeles

by

Tabashir Zahra Sadegh-Nobari

Doctor of Philosophy in Public Health

University of California, Los Angeles, 2016

Professor May-Choo Wang, Chair

Childhood obesity has been declared the most important public health issue of the 21st century by the World Health Organization. In the United States, the prevalence of obesity among children aged 2-19 years increased three-fold in the past forty years. In recent years, this prevalence has begun to plateau and even decrease among preschool-aged children. For example, in Los Angeles County, obesity prevalence among low-income 4-year old children reached a peak of 22.4% in 2009 and then decreased to 20.3% in 2011. However, a recent report showed that this trend was not experienced uniformly across the county and that obesity rates have not abated in some of the poorest neighborhoods. The goal of this dissertation was to evaluate the contribution of socioeconomic factors, at both household and neighborhood levels, to these varying neighborhood trends in obesity rates among low-income children, ages 2-5 years, in Los Angeles County.

Three separate but related studies were conducted. The first study examined trends in early childhood obesity by household and neighborhood socioeconomic characteristics over 12 years (2003-2014). The study used administrative data from children, ages 2-5 years, participating in the Special Supplemental Nutrition Program for Women, Infants and Children (WIC, the second largest federal nutrition assistance program in the country) in Los Angeles County. While childhood obesity rates increased until approximately 2008, a decreasing trend was observed beginning in 2010/2011, a time that coincides with the end of the 2008/09 economic recession. However, the trends varied by socioeconomic indicator, child's age, and child's race/ethnicity with obesity rates among children in some higher SES groups back to 2003 levels, while obesity rates among children in some lower SES groups higher than 2003 levels.

Using the same administrative data, the second study built on the first study by determining whether disparities in early childhood obesity rates by socioeconomic factors have widened in the years following the economic recession when compared to the years prior to the recession. Logistic regression analyses examined whether the time period modified the effect of the socioeconomic factor on early childhood obesity. We found that disparities in early childhood obesity by household-level socioeconomic factors widened for children, although the results varied by child's age. Disparities in early childhood obesity by household education widened for 2- and 3-year-old children and remained the same for 4-year-old children. Disparities in early childhood obesity by household income widened for 3- and 4-year-old children. The disparities in early childhood obesity by neighborhood-level socioeconomic factors (median household income and share of residents living in unaffordable housing, a major source of family financial strain) did not change between the two time periods.

The third study investigated the contribution of this source of family financial strain – unaffordable housing – to early childhood obesity risk and investigated the potential mechanisms involved. The study used survey data gathered from a random sample of WIC families living in Los Angeles County in 2011 and 2014. Analytic procedures included multivariate linear regression and mediation analyses. Unaffordable housing increased the risk of early childhood obesity and household size was found to modify the effect of unaffordable

housing on early childhood obesity. Unaffordable housing, however, was not found to increase adiposity in growing children and mother's mental health, and child's diet and sedentary behavior were not found to be mechanisms of this relationship.

Findings of these three studies contribute to the knowledge and understanding of the mechanisms by which socioeconomic factors and financial strain influence growth and obesity risk in young children from lower income communities.

The dissertation of Tabashir Zahra Sadegh-Nobari is approved.

Michael L. Prelip

Judith M. Siegel

Evelyn A. Blumenberg

Shannon Elise Whaley

May-Choo Wang, Committee Chair

University of California, Los Angeles

2016

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

I would like to thank my dissertation committee for their invaluable insights, expertise and encouragement. Discussing my dissertation at the proposal and dissertation defenses with you and having you bring your expertise to it were the highlight of the doctoral program. May, I cannot thank you enough for mentoring me during the last six years and for all the opportunities you provided. I am in awe of your intellect and your generosity never ceases to amaze me. Dr. Prelip, your kindness, encouragement and focus on the big picture ensured that I did not get stuck in the weeds. Shannon, I am so very grateful for the knowledge and attention you gave to my work, for the unwavering support and trust in me, and for access to the WIC data. Dr. Siegel, thank you for your support and expertise in psychosocial stressors. Evy, thank you for the poverty classes so many years ago and for making my dissertation richer by bringing an urban planning perspective to it.

I am forever grateful to the following individuals who taught me along the way: Steve Wallace, Rick Brown, Kathryn Kietzman, Gilbert Gee, Ted Robles, and Julie Bower. I would like to thank Catherine Crespi in the Department of Biostatistics, Christine Wells at ATS, and Mike Tzen at CCPR for their patience and statistical advice; and the CHS staff for making every step in the doctoral program a little bit easier. I am grateful to Maria Koleilat, Mike Whaley and Lu Jiang at PHFE-WIC for their unending support, and expertise in the WIC data.

I would also like to acknowledge the PFHE-WIC predoctoral fellowship which provided financial assistance and the data necessary to conduct my research. I am also thankful to the California Center for Population Research and the UCLA Department of Health Psychology for the NIGMS T32 Traineeship. Not only did it provide financial assistance, it allowed me to further my training in psychosocial stress, epigenetics and childhood obesity. I would like to thank the Blann family for the Celia and Joseph Blann Fellowship and the Smith family for the Juneal Marie Smith Fellowship in International Nutrition.

I would like to thank Paula Braveman, Sue Egerter and Kristen Marchi for my time at CSDH. It was that experience that sparked my interest in the social determinants of health, including housing, and their importance early in the lifecourse.

While I am forever thankful to the UCLA Fielding School of Public Health for the education and experience I received, I am even more grateful for the friendships I made. As it takes a village to raise a child, it definitely takes one to finish a dissertation. A special thank you goes to Soultana Haftoglou, Pia Chaparro, Taline Marcarian, Stephanie Albert, Roch Nianogo, Héctor Alcalá, Julia Caldwell, Goleen Samari, Annie Ima, Amy Wang, Vivian Alfonso, and Mona AuYong. I would never have finished without you and knowing you were there, even if it was sometimes a text away, meant the world to me. A big thank you to my family of friends who are scattered around the globe and never tired of providing much needed support every step of the way: Pouneh Ghaffarian, Sandy Tchilinguirian, Bourai Raddadi, Mercy Dekker, Angela Thrasher, Ziba Harris, Lucy Anderson, and Zohreh Nobari.

I am forever grateful to my sister, Nassim, for grounding me and making me laugh when I needed it most; my father for instilling in me the courage to go for what might seem unattainable, to persevere until the very last second and for providing me with much needed “courage” along the way; my mother for showing me the importance of addressing inequities and teaching me the true meaning of compassion, an essential trait in public health; and my grandparents for imparting to their children a love of learning.

Lastly, I would like to thank the Will Rogers State Historic Park for providing me with the trails and beauty necessary to find inspiration and keep me sane during the doctoral program.

VITA

Tabashir Z. Sadegh-Nobari

Education

2005	MPH (International Health Epidemiology), School of Public Health, University of Michigan, Ann Arbor, MI
2002	BS (Biochemistry), University of California, Los Angeles, Los Angeles, CA

Professional Experience

12/2014 -present	Research Analyst Public Health Foundation Enterprises WIC Program, Irwindale, CA
2010-2016	Graduate Student Researcher Department of Community Health Sciences, Fielding School of Public Health, University of California, Los Angeles, Los Angeles, CA
Fall 2014	Special Reader for CHS 210 Department of Community Health Sciences, Fielding School of Public Health, University of California, Los Angeles, Los Angeles, CA
2011-2012	Graduate Student Researcher UCLA Center for Health Policy Research, Los Angeles, CA
2006-2010	Research Analyst UCSF Center on Social Disparities in Health, San Francisco, Ca
2005	Graduate Research Assistant University of Michigan School of Public Health, Ann Arbor, MI
2004	Research Intern Institut Salah Aziz, Tunis, Tunisia

Honors and awards

2015-2016	Celia and Joseph Blann Fellowship
2014-2015	Juneal Marie Smith Fellowship in International Nutrition
2012-2014	National Institute of General Medical Sciences T32 Trainee (T32GM084903), California Center for Population Research and Department of Health Psychology, University of California, Los Angeles, Los Angeles, CA

Peer-reviewed Publications

1. Nianogo RA, Wang MC, Wang A, Nobari TZ, Crespi CM, Whaley SE, Arah OA. Projecting the impact of hypothetical early life interventions on adiposity in children living in low-income households. *Pediatr Obes*. 2016 Jun 10. doi: 10.1111/ijpo.12157. [Epub ahead of print]

2. Nobari TZ, Wang MC, Whaley SE. Asian-American mothers' perception of their children's weight: a comparison with other racial/ethnic groups in Los Angeles. *Ethnicity & Disease* 2015; 1:52-57.

3. Chaparro MP, Whaley SE, Crespi CM, Koleilat M, Nobari TZ, Seto E, Wang MC. Influences of the neighborhood food environment on adiposity of low-income preschool-aged children in Los Angeles County: a longitudinal study. *Journal of Epidemiology and Community Health* 2014; 68(11):1027-33.

4. Nobari TZ, Wang MC, Chaparro MP, Crespi C, Koleilat M, Whaley SE. Immigrant enclaves and obesity in preschool-aged children in Los Angeles County. *Social Science and Medicine* 2013; 92:1-8.

5. Miller WD, Sadegh-Nobari T, Lillie-Blanton M. Healthy starts for all: policy prescriptions. *American Journal of Preventive Medicine* 2011; 40(1 Suppl 1): S19-37.

Other (Book chapter, policy briefs, issue briefs, chartbooks)

1. Wang MC, Sawyer AJ, Nobari TZ. Prevention of osteoporosis in children and adolescents. Chapter 16 in Public Health Nutrition: Principles and Practice in Community and Global Health. Burlington, MA: Jones & Bartlett Learning, 2015.

2. Wallace SP, Torres JM, Nobari TZ, Pourat N. Undocumented and uninsured: Barriers to affordable care for immigrant populations. Washington, DC: The Commonwealth Fund, 2013. Available at http://www.commonwealthfund.org/

3. Sadegh-Nobari T, Leos R, Kietzman KG, Wallace SP. Opportunity Knocks: Increasing the Use of Clinical Preventive Services by Older Adults in Diversified Community Settings. Los Angeles, CA: UCLA Center for Health Policy Research, 2012.

4. Egerter S, Braveman P, Sadegh-Nobari T, Grossman-Kahn R, Dekker M. *Issue Brief 6: Education and Health.* Washington, DC: Robert Wood Johnson Foundation Commission to Build a Healthier America, September 2009. Available at: http://www.commissiononhealth.org/Publications.aspx

5. Pollack C, Egerter S, Sadegh-Nobari T, Dekker M, Braveman P. *Issue Brief 2: Housing and Health.* Washington, DC: Robert Wood Johnson Foundation Commission to Build a Healthier America, September 2008. Available at: http://www.commissiononhealth.org/Publications.aspx

6. Braveman P, Sadegh-Nobari T, Egerter S. *Issue Brief 1: Early Childhood Experiences and Health.* Washington, DC: Robert Wood Johnson Foundation Commission to Build a Healthier America, June 2008. Available at: http://www.commissiononhealth.org/Publications.aspx

CHAPTER 1: INTRODUCTION

Childhood obesity is a major public health problem in the United States. Seventeen percent of American children aged 2 to 19 years, and 8.4% of children aged 2-5 years, are obese (Ogden et al. 2014). Reducing obesity risk during childhood is a public health priority. Children who are obese are more likely to have poor mental and physical health and become obese as adults, increasing their risk for chronic diseases (Freedman et al. 2001, Guo and Chumlea 1999, Lobstein, Baur and Uauy 2004).

Energy imbalance is the direct biological cause of obesity leading many interventionists to focus on factors that are proximally related, namely, diet and physical activity behaviors (Hill 2006, Institute of Medicine 2013). However, as described by Swinburn and others (Lake and Townshend 2006, Popkin 2006, Swinburn et al. 2011, Swinburn, Egger and Raza 1999), changes in the macroenvironment (e.g. food, transportation and health-care systems) and microenvironment (e.g. homes, workplaces, schools, neighborhoods) have created an 'obesogenic' (obesity-promoting) environment in many industrialized societies. In the United States, which has one of the highest obesity rates in the world, fast food restaurants and small grocery stores that carry mostly or only non-perishable processed foods are found more frequently in lower income communities (Block, Scribner and DeSalvo 2004, Lovasi et al. 2009, Moore and Diez Roux 2006). At the same time, high crime rates, often experienced by poor communities in the United States, discourage outdoor activities such as walking on the streets or allowing children to play outside. These disparities in obesity-promoting features of the environment between higher and lower income communities are reflected in the higher rates of obesity in lower income communities in the United States. Indeed, a growing body of literature strongly supports the role of social factors in determining obesity risk. Referred to as social determinants of health, family income, race/ethnicity, economic hardship and neighborhood socioeconomic characteristics are considered fundamental causes of health (Braveman, Egerter and Williams 2011, Link and Phelan 1995, WHO CSDH 2008, Wilkinson and Marmot 2003) and have been linked to increased mortality and morbidity (Braveman et al. 2010, Diez Roux and Mair 2010, Elo and Preston 1996, Galea et al. 2011, NCHS 2012, Williams and Sternthal 2010, Winkleby and Cubbin 2003).

This dissertation attempts to contribute to the small but growing body of literature on the role of social determinants of health in obesity development, specifically in early childhood, the period of life when public health intervention may reap the greatest benefits in reducing obesity prevalence for the nation as a whole. In particular, data obtained from 2-5-year-old children enrolled in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) in Los Angeles County from 2003 to 2014 was used to:

(1) Examine the trends in preschool-aged obesity prevalence by household and neighborhood socioeconomic characteristics over this 12-year period;

(2) Determine whether household- and neighborhood-level socioeconomic disparities in childhood obesity rates have changed over time; and

(3) Investigate the contribution of unaffordable housing, an understudied family-level social determinant, to early childhood obesity risk, and the underlying social mechanism.

The WIC data are maintained under the Data Mining Project by Los Angeles-based Public Health Foundation Enterprises-WIC (PHFE-WIC), the largest local agency WIC program in the country. The data are maintained with support from First 5 LA and include socio-demographic and height and weight information on about 3.5 million WIC participants in Los Angeles County from 2003; about 45% of these participants are of preschool age. Each participant's record has been linked to data describing the retail food environment, green space and the socio-demographic characteristics of the census tract of residence. With more than 60% of babies born in Los Angeles County enrolled in the WIC program at birth, and considerable variation in the socio-demographic characteristics of the census tracts in which WIC families live, these data provide a unique opportunity to investigate child, household and neighborhood risk factors for early childhood obesity.

In Chapter 2, the importance of early childhood obesity, as well as findings from the literature on social determinants of health and childhood obesity are discussed. In Chapter 3, the conceptual framework for investigating the influence of the social determinants of health, including unaffordable housing, on early childhood obesity is covered.

In Chapter 4, the trends in early childhood obesity by household and neighborhood-level socioeconomic factors from 2003 to 2014 are examined. Trends in obesity increased until 2008 and then started to decrease in 2010, a time that coincided with the end of the 2008/09 economic recession. However, patterns varied by socioeconomic factor, and child’s age and race/ethnicity. While obesity rates for some of the children in the highest socioeconomic groups are back to 2003 levels, the obesity rates for many children, especially in the lowest socioeconomic groups, are not back to 2003 levels.

In Chapter 5, we further explore the findings from Chapter 4 by examining whether disparities in early childhood obesity by household-level and neighborhood-level socioeconomic factors have actually widened in the years following the economic recession when compared to the years leading up to the recession. We find that disparities in early childhood obesity by household-level socioeconomic factors (household income and household education) have widened for some children. However, disparities by neighborhood-level socioeconomic factors have not changed.

In Chapter 6, the relationship of unaffordable housing and early childhood obesity is investigated. We find that unaffordable housing increases the risk of early childhood obesity; however, it does not increase adiposity in children. The possible social and behavioral pathways by which unaffordable housing influences child’s adiposity were explored and no association was found.

CHAPTER 2: BACKGROUND AND SIGNIFICANCE

Why study childhood obesity?

Childhood obesity has been declared a global epidemic by the World Health Organization and is one of the most serious public health challenges of the 21st century (WHO 2012). Worldwide, about 43 million children under the age of five years are overweight or obese (De Onis, Blössner and Borghi 2010). In the United States, which has one of the highest prevalence rates of obesity, obesity rates have doubled among pre-school aged children, and more than tripled among adolescents over the past 30 years (Fryar, Carroll and Ogden 2012, Ogden et al. 2014). In 2011-12, about 17% of children aged 2-19 years, and 8.4% of children aged 2-5 years, were obese (Ogden et al. 2014).

Children who are obese are more likely to have musculoskeletal, social and psychological problems, suffer from severe chronic health conditions such as non-alcoholic fatty liver disease and type 2 diabetes, and become obese adults and consequently be at increased risk for various chronic diseases including cardiovascular disease and some types of cancer later in life (Freedman et al. 2001, Guo and Chumlea 1999, Lobstein, Baur and Uauy 2004, Singh et al. 2008). Reducing obesity risk in early childhood is a priority since children who have been overweight or obese in early childhood are more likely to be overweight in early adolescence (Nader et al. 2006) and obese children as young as 2-5 years old are more than 4 times as likely to be obese in adulthood (Freedman et al. 2005). Obesity is a costly disease with related health expenditures estimated at $147 billion a year for adults (in 2006) and $14.1 billion for children (in 2002-2005) (Finkelstein et al. 2009, Trasande and Chatterjee 2009).

Definition of obesity

Obesity is operationally defined by having a Body Mass Index [BMI, weight (kg)/height(m)^2] of 30 kg/m^2 or greater for adults, and the 95th percentile or greater of sex- and age-specific growth reference values for children aged 2 years and older (Kit, Ogden and Flegal

2014, Kuczmarski et al. 2002). These commonly accepted definitions have been used to describe obesity prevalence trends in the literature. However, it should be noted that obesity is essentially an excess of body fatness (adiposity) and that while the BMI definitions of obesity have been correlated with increased risk of mortality and morbidity in adults (Berrington de Gonzalez et al. 2010, NHLBI and NIDDKD 1998), their usefulness for young children has been questioned (Burton 2007, Kit, Ogden and Flegal 2014). Since it takes a long time for health conditions like diabetes and cardiovascular disease to develop, it is not clear how to determine increased risk of morbidity in children (Ogden 2004).

Compared to other indices of relative weight, BMI is a better measure of relative weight and adiposity because it is less correlated to height (Eknoyan 2008). However, BMI is not completely independent of height, especially in young children. Further, the association of BMI with adiposity is dependent on body proportions (Garn, Leonard and Hawthorne 1986). In young children whose body proportions are changing rapidly, weight-for-height z-scores (WHZ) derived from sex- and age-specific growth reference values, are a preferred measure since they are independent of height (Jones et al. 2012).

Etiology of childhood obesity

The primary function of adipose tissue (body fat) is to store energy and insulate the body (Hill 2006). Obesity, which is an excess of adipose tissue, is due to an imbalance of energy intake and expenditure (Kit, Ogden and Flegal 2014). Energy intake is determined by diet, specifically the amount and types of food and beverages consumed, while energy expenditure is affected by physical activity level as well as metabolic rate (Kit, Ogden and Flegal 2014). This metabolic regulation occurs with the help of insulin (a hormone produced in the pancreas) and leptin (a hormone produced by adipocytes, i.e., fat cells) which communicate the body's adiposity levels (energy storage levels) to the hypothalamus in the brain. The hypothalamus then controls energy intake and expenditure accordingly (Skelton et al. 2011). However, many different signals are involved in the control of this metabolic regulation and these signals can be influenced by genes, epigenetic modifications, environmental factors, and chronic stress (Skelton et al. 2011). Chapter 3 on theory includes a discussion of the biological mechanism by which chronic stress can disrupt metabolic regulation.

Risk factors for childhood obesity include behavioral factors that can lead to energy imbalance such as family food purchasing and family meal-time behaviors, TV watching, and environmental factors that influence diet and physical activity such as convenient access to healthy and affordable foods and safe recreational facilities for children to engage in physical activity (Health and Human Services 2005, Skelton et al. 2011).

Childhood obesity and social determinants of health

Social determinants of health are the social and economic factors that affect people's health such as socioeconomic status (SES), racial discrimination, income, education, poverty, housing and neighborhood socioeconomic conditions (Braveman, Egerter and Williams 2011, Woolf and Braveman 2011). These fundamental causes or "upstream" factors influence people's health through their exposure to environmental risk factors, their health behaviors, beliefs and knowledge, and their access to material resources and health care (Braveman, Egerter and Williams 2011, Woolf and Braveman 2011). The unequal distribution of these upstream factors creates avoidable and unjust inequalities in health ("health disparities") by shaping behaviors, determining access to resources, and knowledge, and influencing physiological mechanisms (Adler and Stewart 2010b, Braveman 2006, Braveman, Egerter and Williams 2011). Understanding the impact of these fundamental causes on childhood obesity is critical for building a comprehensive framework for investigating the etiology of childhood obesity and designing effective population level interventions.

In the following section, I will discuss the established social determinants of health, namely race/ethnicity, SES, household income, household education, and neighborhood socioeconomic profile. [Note that the term neighborhood SES while commonly used does not have clear meaning]. This will be followed by a discussion of the gaps in the literature.

Race and ethnicity

Racial and ethnic disparities in childhood obesity are observed in the United States. Data from national surveys show that in general American Indian children and adolescents have the highest prevalence of obesity followed by Black and Mexican-American children and adolescents, and Non-Hispanic whites and Asians have the lowest (Wang 2001, Wang 2011). In 2011-2012 NHANES data, 22.4% of Hispanic children and 20.2% of NH black children aged 2-19 years are obese versus 14.1% of NH white children and 8.6% of Asian children. These disparities are evident early on as well (Anderson and Whitaker 2009, Ogden et al. 2012, Ogden et al. 2014). In 2011-2012, 16.7% of Hispanic and 11.3% of NH black children aged 2-5 years in the U.S. were obese compared to 3.5% of NH white and 3.4% of Asian children (Ogden et al. 2014). Racial/ethnic differences in obesity tend to be larger among girls than boys and the racial/ethnic gaps in childhood obesity have widened in the U.S. since the late 1970s (Wang 2011).

In the United States, the effects of race/ethnicity on health are often intertwined with those of socioeconomic factors. With regard to childhood obesity specifically, the high rates seen in Black, Hispanic and American Indian children are likely due to social factors such as household income, education, and neighborhood quality (Caprio et al. 2008). Differences in childhood obesity could also be due to cultural factors regarding body size (Caprio et al. 2008). Genetics and different levels in the metabolic regulation signals may also play a role (Caprio et al. 2008). Additionally, BMI cutpoints may not be appropriate for all racial/ethnic groups. Lower BMI cutpoints for Asians have been recommended since they have a higher mortality risk at the same BMI as other ethnic groups (Wang 2013). This could partly be due to a difference in the distribution of body fat among Asians (Wang 2013).

Although it has not been studied among children, racial discrimination might play a role. Using data from the National Latino and Asian American Study (NLAAS), one study found that the probability of Asian American adults being obese was twice as high if they experienced racial discrimination, defined as perceived unfair treatment due to race (Gee et al. 2008). However, Hunte and Williams (2009) examined perceived racial discrimination among other racial/ethnic groups and found that it was not associated with increased risk of obesity in black or Hispanic adults. Interestingly, it was associated with increased risk among Whites of Irish, Jewish, Polish, and Italian ethnicity, groups who have suffered discrimination in the past (Hunte and Williams 2009).

Socioeconomic status

Frequently operationalized as education, income or occupation, socioeconomic status (SES) is a concept that refers to an individual's position in society and their power, prestige and access to resources (Adler and Stewart 2010a, Braveman 2006). SES is associated with increased mortality and morbidity (Braveman et al. 2010, Diez Roux and Mair 2010, Elo and Preston 1996, Galea et al. 2011, NCHS 2012, Williams and Sternthal 2010, Winkleby and Cubbin 2003). SES is also associated with obesity, including childhood obesity. In 1989, Sobal and Stunkard conducted a comprehensive review of cross-sectional studies examining SES and obesity in developed and developing countries. They found that among children in developed countries, the relationship between SES and obesity was inconsistent (Sobal and Stunkard 1989). Approximately a third of the 34 studies reviewed found a positive relationship, a third found a negative relationship and a third did not find any relationship. This was true regardless of gender and most studies found similar results for both girls and boys. This inconsistent relationship was also found for the 14 American studies. Sobal and Stunkard hypothesized that the variability was due to differences in how SES was measured, timing of the study, and age of the children. The populations sampled were also different.

Since the Sobal and Stunkard review, studies have mostly found the relationship between SES and childhood obesity to be negative, with lower SES associated with increased risk of obesity. Shrewsbury and Wardle (2008) conducted a review of the literature from developed countries on SES and obesity among children 5-18 years. A majority (42%) of the 45 studies reviewed found a negative relationship between SES and obesity. SES was defined as parents' education, occupation, family income, or an index or neighborhood SES. Approximately a quarter of studies found no association and the remaining found either a negative or no relationship among the study's subgroups (Shrewsbury and Wardle 2008). The authors did not find a positive association in any study.

Household income

In the U.S., household income is negatively associated with obesity in children and there tends to be a dose-response relationship (Ogden et al. 2010b, Strauss and Knight 1999, Wang and Zhang 2006). In 2005-2008, 12.0% of girls and 11.9% of boys aged 2-19 years living in families with incomes greater or equal to 350% of the federal poverty level (FPL) were obese compared to 15.8% and 17.4% of girls and boys, respectively, living in families with incomes between 130% FPL and < 350% FPL (Ogden et al. 2010b). Obesity prevalence was 19.3% and 21.1% in girls and boys living in families with incomes < 130% FPL (Ogden et al. 2010b).

However, the relationship is not as stark as it used to be and it varies by child's age, gender and race/ethnicity (Ogden et al. 2010b, Wang and Zhang 2006). For instance, household income is negatively associated with overweight in boys 2-9 years old but it is not associated in boys 10-18 years old (Wang and Zhang 2006). Household income is negatively associated with overweight in adolescent white girls but positively associated with overweight in adolescent black girls (Wang and Zhang 2006). This racial/ethnic difference among adolescent girls might be partially due to different perceptions regarding ideal body size and to increased exposure to chronic stress among black girls (Adams et al. 2000, Williams et al. 2010).

The association between household income and childhood obesity seemed to be weakening until the early 2000s due to higher income children experiencing increased rates of obesity (Wang and Zhang 2006). The authors hypothesized that when computers and computer games became more affordable in the 1990s higher income children were able to purchase them and this subsequently influenced their physical activity levels. Their levels started to resemble those of lower income children who watched more TV than the higher income groups (Wang and Zhang 2006). From the early to the late 2000s, however, it appears that obesity among children aged 10-17 years of lower-income families increased more than among children of higher income families, with those in poverty experienced the greatest increase (Babey et al. 2010, Singh, Siahpush and Kogan 2010b).

Most of the evidence on household income and childhood obesity come from cross-sectional studies; however, a few longitudinal studies examining economic predictors of childhood obesity have been conducted (Demment, Haas and Olson 2014, Dubois and Girard 2006, Jones-Smith et al. 2014, Lee et al. 2014, Zilko and Cubbin 2013). They have found mixed results which could be due to the timing of low household income (e.g., at birth or later on), the measure used and/or when and where the study occurred. In a Quebecois cohort of children born in 1998, household income before pregnancy was found to be negatively and significantly associated with obesity at 4.5 years (Dubois and Girard 2006). In a study of 10 cities in the US, Lee et al. (2014) found that poverty before 2 years of age increased the risk of obesity by 15.5 years of age. When using a SES composite index based on household income and both parents' education and occupations, Jones-Smith et al. (2014) found similar results among the Early Childhood Longitudinal Study-Birth Cohort, however, their findings varied by race/ethnicity. Among NH whites, Hispanics and Asians, SES was negatively associated with overweight/obesity after the children were 9 months old. A relationship was not found among American Indians or blacks. The authors hypothesized that the SES relationship might become apparent in blacks and American Indians when they are older (Jones-Smith et al. 2014). One limitation of the study is that the authors used BMI to determine overweight/obesity for children less than 2 years old instead of weight-for-height z. As discussed earlier (pg 5), the validity of BMI as an indicator of adiposity in growing young children has not been established. Contrary to these findings, Zilco and Cubbins (2013) found that among the children born to women of the National Longitudinal Survey of Youth 1979 (NLSY79), becoming poor between the ages of 4 and 14 years decreased a child's risk of overweight or obesity compared to children who never experienced poverty, adjusting for child's and mother's sociodemographics.

The differences in obesity by income can be partly due to economic resources. Households with greater income are able to afford health care, healthy foods, and be able to pay for housing in a safe neighborhood with access to grocery stores, parks and recreational areas (Braveman, Egerter and Barclay 2011, Schreier and Chen 2013). Low-income households, however, are more likely to have poor diets, live in poor and unsafe neighborhoods, and experience more chronic stressors (Adler and Stewart 2010a, Braveman, Egerter and Barclay 2011, Lovasi et al. 2009).

Household education

During their review of studies from developed countries, Shrewsbury and Wardle (2008) found that three-quarters of the studies that examined parents' education as an indicator of SES found a negative relationship between parents' education and childhood obesity. This negative relationship exists in the US as well (Ogden et al. 2010b, Strauss and Knight 1999). Using 2005-2008 NHANES data, Ogden et al. (2010) find that 8.3% of girls and 11.8% of boys aged 2-19 years in households where the highest level of education is at least a college degree are obese compared to 20.4% of girls and 21.1% of boys in households where the highest level of education is less than a high school degree (Ogden et al. 2010b). A dose-response relationship between household education and childhood obesity also exists. As with income, the relationship between household education and childhood obesity is not as clear-cut and varies by race/ethnicity and gender. Among NH white and black girls aged 2-19 years a significant negative relationship exists (Ogden et al. 2010b). Among boys, a negative relationship existed for NH white and Mexican-American children, however, it was non-significant.

Between 1988-1994 and 2005-2008, the prevalence of childhood obesity significantly increased in all households among both girls and boys, except for girls in households where the highest level of education is at least a college degree (Ogden et al. 2010b). From the early to the late 2000s, obesity among children of households with less than a high school degree increased significantly more than children living in households with at least 12 years of education (May et al. 2013, Singh, Siahpush and Kogan 2010b). However, the study that used measured height and weight data found that this was true for girls but not boys (May et al. 2013). These trends varied according to race/ethnicity with NH white girls demonstrating this pattern. Among NH black girls, the prevalence of obesity also increased among the higher educated groups (May et al. 2013).

The studies mentioned above grouped children of all ages together. Less is known about the impact of education on very young children. Kimbro et al. (2013) found 5-year old children whose mothers had more than a high school education to be significantly less likely to be obese after adjusting for child and family socio-demographics. However, there was no significant difference between the children whose mothers had a high school degree and those whose mothers had less than a high school degree. Among low-income pre-school aged WIC children in Los Angeles County, Chaparro et al. (2014) and Nobari et al. (2013) found that mother's education was negatively associated with adiposity after adjusting for child and family socio-demographics (Chaparro et al. 2014, Nobari et al. 2013). Contrary to the two studies, Barroso et al. (2012) did not find an association of mother's education and child weight-for-height z-score among low-income WIC children in Texas (Barroso et al. 2012). It could be that a relationship with education is not evident among very young children, i.e., aged 1-2 years, or it could be their use of a dichotomous education measure (high school graduate or not) which did not allow for enough variability. Chaparro et al. (2014) and Nobari et al. (2013) used a 3-category education measure.

Most of the evidence on education and childhood obesity come from cross-sectional studies; however, two longitudinal studies have examined mother's educational attainment and risk of childhood obesity. In an Australian birth cohort, low mother's educational attainment at birth was associated with increased risk of obesity in adolescence (Chivers et al. 2012). In the previously-mentioned Quebecois birth cohort study, mother's education was not significantly associated with obesity at 4.5 years (Dubois and Girard 2006). It could be that the impact of mother's education varies by country. In Quebec, education might not be a good indicator of SES or policies might exist that negate its influence. Furthermore, the Australian study used a measure that encompassed aspects of occupation (e.g., trade/apprenticeship) which includes other dimensions of SES.

The association of education with obesity may not only be due to the financial resources that increased education generally provides through better occupation. Education also provides health literacy and improves health behaviors, such as healthier diets and physical activity, (Chandola et al. 2006, Cutler and Lleras-Muney 2006, Kenkel 1991, Lleras-Muney 2005) and might also influence childhood obesity through the home cognitive and emotional environment (Strauss and Knight 1999).

Neighborhood SES

Neighborhood SES is frequently measured by median household income, percent of residents in poverty or percent of residents without a high school degree. Shrewsbury and Wardle (2008) reviewed seven studies on neighborhood SES and found mixed results. Studies either found a negative relationship, no relationship or a negative relationship in certain subpopulations (Grow et al. 2010, Shrewsbury and Wardle 2008). However, these studies did not use multilevel analyses that also adjusted for family and individual level factors (Grow et al.

2010). Greves-Grow et al. (2010) examined multiple measures of the neighborhood socioeconomic environment with obesity risk in insured children aged 6-18 years in Washington. Conducting spatial analysis that took into consideration the effect of adjacent census tracts and that adjusted for child age, gender and health plan status as a marker of household income, the authors found that a decrease in tract-level median household income, a decrease in home ownership, an increase in women with less than a high school education, and an increase in single-parent households were each associated with a significant increased odds of obesity.

Using a nationally-representative dataset and conducting multilevel analyses, Kimbro et al. (2013) found that 5-year old children living in low SES neighborhoods (i.e., greater percentage of households living in poverty or adults with less than a high school degree) were at significantly higher odds of being obese, after adjusting for child and family sociodemographics and neighborhood population density. Using neighborhood median income as the neighborhood SES measure, Nobari et al. (2013) found similar findings among low-income preschool-aged children in Los Angeles County.

Few studies have examined trends in childhood obesity by neighborhood SES. One ecological study examined trends among preschool-aged children participating in WIC in Los Angeles County. Chaparro et al. (2014) found that census tracts with increasing obesity prevalence rates were more likely to be disadvantaged, i.e., a greater percentage of less educated, poorer, or minority residents, compared to tracts that were more advantaged.

Most of the studies examining neighborhood SES and childhood obesity are cross-sectional. Among toddlers participating in WIC, Chaparro et al. (2014) found that after adjusting for child's and mother 's demographics and neighborhood food environment, children living in the lowest income neighborhoods were at increased likelihood of having higher adiposity one year later at age 3 than children living in the highest income neighborhoods. While the study examined obesity in young adulthood, Lee et al. (2009) used three waves of the National Longitudinal Study of Adolescent Health data and found that neighborhood poverty (i.e., census tract-level percent of families living in poverty) in adolescence significantly increased the likelihood that children would remain obese in young adulthood, even after adjusting for sociodemographics and health behaviors (Lee, Harris and Gordon-Larsen 2009). However, neighborhood poverty was not associated with normal weight children becoming obese in young adulthood.

These findings highlight the impact of neighborhoods on obesity risk. Neighborhoods can influence children’s diet, physical activity, and chronic stress through the physical environment, such as poor access to supermarkets, recreational spaces, and sidewalks, and through the social environment such as decreased social capital and safety, increased crime, and unhealthy social norms (Lovasi et al. 2009, Schreier and Chen 2013).

What are some of the issues and gaps in the literature on SES and childhood obesity?

Most of the evidence on family and neighborhood SES and childhood obesity come from observational studies where we cannot infer causality. In the literature on the relationship between SES and health, there is an issue of whether SES causes the health outcome. It could be that poor health influences SES or that there is a third factor responsible for the relationship, such as high discount rates, genetics, or self-control (Borghans and Golsteyn 2005, Braveman, Egerter and Williams 2011, Cutler, Glaeser and Shapiro 2003, Fuchs 2004, Smith, Bogin and Bishai 2005). For adults, obesity can affect SES through decreased educational attainment or income. Since parents’ SES is used as a measure for children it is highly unlikely that a child’s obesity will influence his or her parents’ SES. The relationship could be due to a third factor. High discount rates would not apply until later, however, genetics might be a factor since children share their parents genome (Baum and Ruhm 2009).

Trends by income and education have shown a possible increase in obesity among lower SES groups. However, no studies have examined the trends since the late 2000s, when families were still reeling from the Great Economic Recession. Additionally, most studies examined trends by household income and none examined trends by both a household and a neighborhood level SES measure. It is important to use various SES measures since they reflect different dimensions of socioeconomic status and may therefore shed light on the etiology of childhood obesity.

Studies examining trends in obesity by SES have also either grouped all ages of children together or have focused on older children and adolescents. Less frequently have trends in obesity by SES been examined in young children. Except for the study conducted by Chaparro et al. (2014), trends among low-income pre-school aged children are generally only examined by race/ethnicity and not by family or neighborhood SES (Dalenius K et al. 2012, Pan et al. 2012, Sekhobo et al. 2013). Yet socioeconomic differences in obesity exist among low-income pre-school aged children. Analyses of the 2011 Pediatric Nutrition Surveillance System (PedNSS) data on children who participate in federally funded maternal and child health and nutrition programs, found that 14.2% of children in families ≤ 50% FPL were obese compared to 11.8% of children in families with 151-185% FPL (CDC 2014). Small socioeconomic differences may have a greater impact among vulnerable low SES children. While trends in obesity are generally examined by SES or race/ethnicity, it is important to examine both together.

Many studies do not examine SES as a main independent predictor. Family and neighborhood SES variables are controlled for in analyses that examine other main effects. Some of these studies used SES variables that had 3 categories. Sample size permitting, it is important to examine more categories to determine whether a dose-response relationship exists. Evidence of one would suggest that a causal relationship exists between the SES variable and childhood obesity (Braveman, Egerter and Williams 2011). Evidence of a threshold effect would suggest that interventions should be targeted at the most vulnerable groups (Braveman et al. 2010).

Quite a few studies used data from large nationally representative surveys like NHANES or the Early Childhood Longitudinal Study-Birth Cohort that use measured height and weight data to determine children's BMI percentiles. However, a couple studies did use data from surveys that had parent- or child-reported height and weight measures (Babey et al. 2010, Singh, Siahpush and Kogan 2010b). These are less accurate since parents may underreport their children's height or weight. This bias can vary according to the child's age and the parent's socioeconomic status (Weden et al. 2013).

Researchers have infrequently examined chronic stress as one of the mechanisms by which SES influences childhood obesity, even though chronic stress is one of the mechanisms by which SES influences health (Adler and Stewart 2010a, Adler and Stewart 2010b). Chronic psychosocial stress occurs when environmental demands from interactions with the social environment "tax or exceed the adaptive capacity of an organism, resulting in psychological and biological changes that may place a person at risk for disease" and anyone of these stages lasts for a relatively long period of time (Baum, Cohen and Hall 1993, Cohen, Kessler and Gordon 1995). Individuals at lower socioeconomic status are more likely to experience chronic stress through negative life events, job stress resulting from high demand and low control, economic hardship, smaller social networks, and neighborhood factors such as crime, noise and pollution (Adler and Stewart 2010b, Baum, Garofalo and Yali 1999). In addition to children being directly exposed to some of these stressors, parents' chronic stress can affect the quality of care and resources a child receives (Thompson 2014). Very young children are especially vulnerable to chronic stress since they depend on their caregivers to regulate their biological response to stress (Gunnar and Quevedo 2007).

Emerging literature suggests that chronic psychosocial stress, such as parent's poor mental and/or physical health, negative life events, chaotic home environments, lack of emotional support, housing instability, and measures of financial strain, may play an important role in rising obesity rates (Garasky et al. 2009, Gundersen et al. 2011, Lumeng et al. 2014, Nobari, Wang and Crawford 2014). One chronic stressor that has largely been ignored in the literature on childhood obesity is unaffordable housing.

Unaffordable housing and childhood obesity

The US Department of Housing and Urban Development (HUD) defines unaffordable housing as spending more than 30% of a family's income on housing related costs, such as mortgage payments, rent, and utilities. Families who spend more than 50% of income on housing are severely burdened by housing costs. In 2012, nearly 41 million households in the United States were burdened by housing costs, including nearly 20 million who were severely burdened (Joint Center for Housing Studies 2014). Low-income and minority households are more likely to be cost-burdened, especially severely burdened (Joint Center for Housing Studies 2014). Among poor households in the U.S., 77% were burdened with housing costs while 67% were severely burdened.

Housing provides shelter, stability, and protection to families and is therefore important to health and well-being (Pollack et al. 2008). A number of features of the housing unit such as physical housing quality, crowding, residential mobility, housing affordability, and homeownership have been studied in relation to child health and development (Leventhal and Newman 2010). Although housing is one of the largest expenses families pay, the impact of unaffordable housing on health is rarely studied (Leventhal and Newman 2010, Quigley and Raphael 2004), possibly due to potential policy solutions having to include unpopular income supplements (Leventhal and Newman 2010). Among the few studies that have examined the influence of unaffordable housing on health (Harkness and Newman 2005, LACDPH 2015, Ma, Gee and Kushel 2008a, Pollack, Griffin and Lynch 2010), Ma et al. (2008) analyzed data from the National Survey of America's Families and found that unaffordable housing increased the odds of low-income families postponing medical care and needed medications for their children. These findings were significant after adjusting for family and child sociodemographics, insurance status, food insecurity and receipt of WIC and food stamps. The authors defined unaffordable housing as not being able to pay mortgage, rent or utility bills in the past 12 months. The odds for each outcome increased when the families also moved in with someone else due to the inability to pay for housing. Controlling for sociodemographics and neighborhood environment, Pollack et al. (2010) examined the association of perceived unaffordable housing with a number of health indicators among adults in southeastern Pennsylvania. The authors found that it significantly increased the odds of fair or poor health, arthritis, hypertension and cost-related health care and prescription nonadherence.

Unaffordable housing might also increase the risk of childhood obesity through economic hardship that could decrease a family's financial resources for a healthy diet and safe physical activity opportunities for their children. Economic hardship is also a chronic stressor that increases the likelihood of the home environment being cold and unsupportive thereby increasing the child's own chronic stress.

One study examined unaffordable housing as part of an index of housing-related stressors that included doubling up, sending the child to live with someone else, and moving to cheaper housing. The authors found that the index was not significantly associated with overweight and obesity in children aged 5-17 years who participated in the second Child Development Supplement (CDS-II) of the Panel Study of Income Dynamics (PSID) in 2002-2003 (Garasky et al. 2009). The lack of association could be because the authors examined unaffordable housing as part of an index. Examining unaffordable housing separately from other housing indicators is important since the relationship with obesity and the mechanisms involved are likely to be very different. Furthermore, Garasky et al. (2009) examined the relationship among a nationally representative sample of children. Unaffordable housing might only have a significant effect on low-income families since they already have relatively little income to devote to housing costs (Harkness and Newman 2005). The authors also examined the relationship among older children. There are critical periods in development, and unaffordable housing might have an impact on very young children who are still developmentally dependent on their parents.

In the above-mentioned study on adults in Pennsylvania, Pollack et al. (2011) examined the relationship of unaffordable housing with obesity but did not find a relationship. The authors considered any housing that was perceived to be unaffordable and not just housing that was a severe cost burden (Pollack et al. 2010). The authors also used self-reported height and weight to calculate BMI and not actual measures of height and weight. Additionally, housing costs may have a greater impact on children than adults who might be able to weather effects better.

It should be noted that while HUD has an objective definition of what is affordable housing, no unique definition exists (Quigley and Raphael 2004). Unaffordable housing generally refers to all housing related costs. While sometimes only mortgage and rent are considered, some studies have included utility bills and/or property taxes in their measure of unaffordable housing (Ma, Gee and Kushel 2008b, Pollack, Griffin and Lynch 2010). Affordable housing is dependent on a family's income and family size. The impact of unaffordable housing is very different for a family making $100,000 than it is for a family making $24,000. Additionally, a family of 2 on $24,000 has an easier time spending 30% for housing than a family of 2 adults and 3 children.

Affordable housing is also dependent on market housing prices, the supply of housing and its quality, the ability to take out a loan, policies that influence housing markets, and the choices families make in how to allocate their financial resources (Quigley and Raphael 2004). The reason families make these choices might also influence the outcome of interest (Leventhal and Newman 2010). Given these reasons, some researchers examine neighborhood-level unaffordable housing such as the fair market rent of the area. Harkness and Newman (2005) examined housing markets in the metropolitan area and found that poor children aged 6-17 years living more affordable housing markets had better parent-reported health than poor children living in less affordable housing markets. An extreme of unaffordable housing, Arcaya et al. (2013) found that among adults in the Framingham Offspring Cohort study living near foreclosures increased the odds of being overweight.

CHAPTER 3: THEORY

The proposed dissertation aims to examine socioeconomic disparities in early childhood obesity prevalence trends in Los Angeles County and the role of a financial chronic stressor, unaffordable housing as indicated by severe housing cost burden, in the etiology of early childhood obesity. As discussed in the previous chapter, obesity is directly caused by energy imbalance. In this chapter, I will begin by discussing the biological theory of how chronic stress can influence energy imbalance. I will then discuss three theories that inform how socioeconomic factors and financial strain can influence childhood obesity: Brofenbrenner's Ecological Systems Theory, the Family Stress Model of Economic Hardship and the Risky Families Model. I will present the limitations of each in relation to the proposed study, and will finish by discussing how the conceptual framework can be applied to understand how family SES, neighborhood SES and unaffordable housing can each influence the risk of obesity in very young children.

Biological Theory: The Hypothalamic-Pituitary-Adrenal (HPA) Axis and Cortisol

There are two main systems in the body that regulate our response to stress and allow us to maintain homeostasis and allostasis: the sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenal (HPA) axis. While the two systems are connected, much of the research on chronic stress and obesity has focused on the role of the HPA axis and cortisol (Bjorntorp 2001, Scott, Melhorn and Sakai 2012).

When an individual experiences physical or psychosocial stress the hypothalamus is activated and corticotropin releasing hormone (CRH) is secreted (see Figure 3.1). CRH stimulates the release of adrenocorticotropic hormone (ACTH) from the anterior pituitary gland. ACTH travels through the blood to the adrenal cortex and stimulates the secretion of cortisol, a glucorticoid (GC) (a type of steroid hormone). Inactive cortisol is transported in the bloodstream to the target tissues where it is activated by an enzyme. Cortisol then binds to glucocorticoid receptors and this regulates the transcription of a number of genes in the cell (Bose, Olivan and Laferrere 2009).

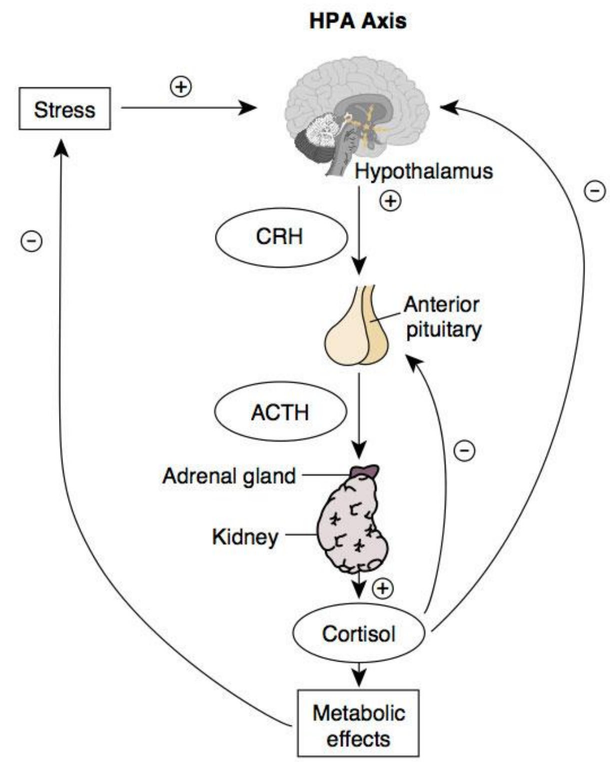


Figure 3.1. Hypothalamus-Pituitary-Adrenal Axis (HPA)
Source: http://php.med.unsw.edu.au/embryology/

Cortisol is important for normal growth and development, metabolism and maintaining homeostasis. Cortisol has a diurnal pattern that decreases throughout the day but has a peak shortly after waking and a smaller one after lunch. Under acute stress, the HPA axis is activated and there is a peak in the secretion of cortisol. When the HPA axis functions normally, the elevated levels of cortisol shut off the axis through a negative feedback mechanism and cortisol returns to basal levels (Bjorntorp 2001). However, chronic exposure to stress can induce a dysregulation in the HPA axis where it takes longer for the axis to shut down, therefore cortisol levels stay high for a longer period of time (Bjorntorp 2001).

During times of acute stress, cortisol suppresses hunger so that the body's energy can be used for the fight or flight response. When the HPA axis is activated CRH is released into the hypothalamus and inhibits a set of neurons that are responsible for stimulating eating (Sominsky and Spencer 2014). Cortisol also mobilizes energy by increasing glucose availability through protein breakdown, gluconeogenesis (formation of glucose), and lipolysis (breakdown of lipids). However, during periods of chronic stress, cortisol increases the accumulation of fat and stimulates appetite (Sominsky and Spencer 2014).

Cortisol and fat accumulation

To accumulate fat, cortisol binds to the glucocorticoid receptors (GR) which activates a certain enzyme and leads to an increase of triglycerides in adipocytes (fat cells). GR are greater in visceral adipose tissue than in subcutaneous adipose tissue therefore increasing visceral fat (Bjorntorp 2001). In the presence of the hormone insulin, cortisol also inhibits the lipid-mobilizing system, resulting in the retention of triglycerides. An example of this is seen among individuals with Cushing's disease who have high levels of cortisol and insulin and high levels of visceral adipose tissue (Bjorntorp 2001).

Cortisol and appetite

During times of chronic stress cortisol can increase appetite with the help of insulin, leptin and ghrelin. Under acute stress, cortisol suppresses food intake by stimulating insulin secretion from the pancreas. Insulin normally decreases food intake by acting at the hypothalamus and at the ventral tegmental area in the brain to decrease the dopaminergic reward of food (Sominsky and Spencer 2014). However, under chronic stress cortisol increases insulin levels but also increases insulin resistance by diminishing insulin's actions on the hypothalamus (Dallman 2010, Sominsky and Spencer 2014). This results in insulin's decreased capacity to suppress appetite (Sominsky and Spencer 2014). Due to the insulin resistance caused by cortisol, insulin no longer sufficiently suppresses the dopaminergic neuron-reward pathways. Food therefore needs to provide increasing levels of "reward" which highly palatable, calorically-dense foods, high in fat and sugar do (Sominsky and Spencer 2014). Additionally, the reward activation provided by these foods activates a negative feedback mechanism of the HPA axis, thereby shutting the axis off and reducing cortisol levels (Sominsky and Spencer 2014). The learned association between eating highly palatable, calorically-dense foods and feeling less stressed can easily become a habit, with the prefrontal cortex no longer involved in controlling behavior. People then end up automatically reaching for the foods when they feel stressed (Dallman 2010).

Cortisol also stimulates fat cells to release leptin, a hormone that suppresses appetite and signals satiety. However, cortisol also decreases the brain's sensitivity to leptin (Sominsky and Spencer 2014). Individuals who are obese have high levels of leptin but are resistant to its effect. Although the mechanism is still unclear, animal and human studies show that cortisol induces leptin resistant obesity (Bjorntorp 2001, Sominsky and Spencer 2014).

Cortisol can increase ghrelin, a hormone secreted from the stomach that signals hunger and stimulates appetite. Ghrelin stimulates peptides in the hypothalamus which in turn stimulates appetite (Sominsky and Spencer 2014). However, not everyone responds to chronic stress by increasing food intake. Some people, especially unrestrained eaters, reduce their intake. It is believed that ghrelin may influence whether a person increases or decreases their food intake (Sominsky and Spencer 2014). Stress-induced ghrelin levels are unchanged by food intake in emotional eaters (people who eat highly caloric, palatable food when stressed), but are quickly restored to baseline by food intake in non-emotional eaters (people who eat less or the same when stressed). The same attenuated ghrelin response to food is observed in obese individuals with a greater percent body fat (Raspopow et al. 2010, Raspopow et al. 2014).

People who eat when stressed and people with excess adiposity may need to eat relatively more palatable food to decrease the cortisol-stimulated ghrelin levels (Sominsky and Spencer 2014).

Chronic stress can therefore lead to elevated levels of cortisol which leads to increased fat in the visceral adipose tissue and increase intake of food, especially highly palatable, energy-dense food. However, the cortisol-obesity pathway is not unidirectional. Adipose tissue secretes cytokines which activate the HPA axis, leading to an increased secretion of cortisol (Foss and Dyrstad 2011). Adipose tissue can also increase levels of cortisol through an enzyme that activates the inactive form of cortisol. Cortisol then binds to the glucocorticoid receptors and initiates the above-mentioned events that lead to fat accumulation in visceral adipose tissue and insulin resistance (Spencer and Tilbrook 2011, Stomby et al. 2014). Although it is not believed that local levels of this activated cortisol have a systemic effect (Stimson et al. 2009).

Ecological Systems Theory

A framework for understanding how household SES, neighborhood SES and unaffordable housing can influence the risk of childhood obesity is Bronfenbrenner's Ecological Systems Theory (EST). Originally formulated for human development in the 1970's, Urie Bronfenbrenner's Ecological Systems Theory (frequently called the Social Ecological Model) posits that the context or the ecological environment in which a child develops must be considered in order to understand the development of a child's characteristic (Bronfenbrenner 1994). EST states that five nested subsystems exist: the microsystem, mesosytsem, exosystem, macrosystem and chronosystem (see Figure 3.2). These subsystems can be thought of as a set of Russian dolls, one within another, and are considered from the standpoint of the developing child. The factors within the subsystems can interact with each other and the subsystems can interact with adjacent subsystems.

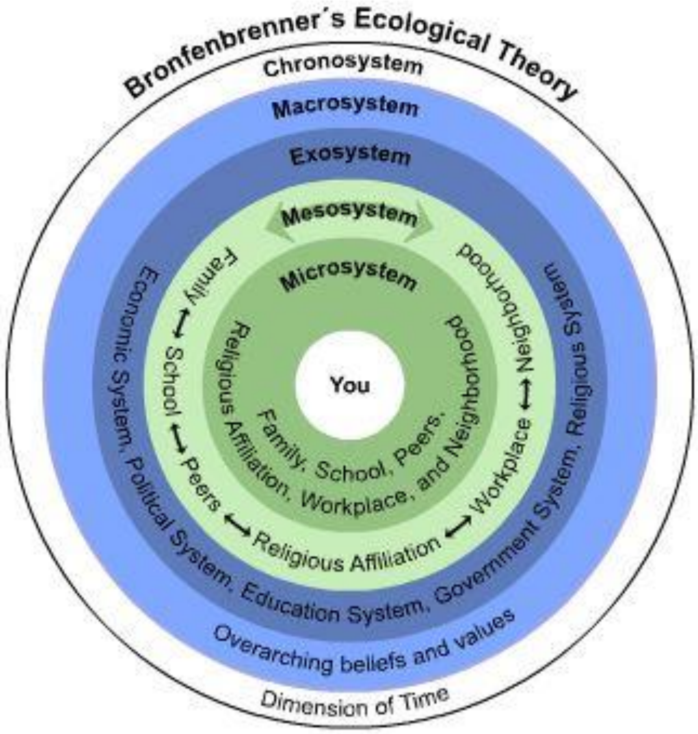


Figure 3.2. Bronfenbrenner's Ecological Systems Theory
Source: http://seansturm.wordpress.com/2009/06/21/the-writing-zone-according-to-ecological-systems-theory/

The *microsystem* consists of the developing child's interactions with his or her immediate environment, such as home, daycare and the neighborhood (Bronfenbrenner 1977). Within these immediate environments, the child engages in certain activities, in certain roles, for certain periods of time (Bronfenbrenner 1977). Microsystems facilitate or constrain the child's behaviors, activities, and roles (Bronfenbrenner 1994). A reciprocal relationship exists between the child and the microsystem with each influencing the other. For instance, a mother influences her child but how the child interacts with his or her mother can also influence the mother's behavior towards her child.

The *mesosystem* consists of the interactions between the child's microsystems, such as the communication between parents and daycare providers regarding a child. The *exosystem* consists of formal and informal social structures that indirectly influence the child by directly impacting that child's immediate settings. At least one of these settings cannot contain the child (Bronfenbrenner 1994). Governmental agencies, parents' workplace, family social networks, mass media, would all be considered exosystems for a child. Programs and policies such as the WIC food package change would also fall under exosystems. The *macrosystem* refers to the larger culture or subculture (i.e., the economic, social, educational, legal and political systems) that implicitly and explicitly shapes the micro-, meso- and exosystems (Bronfenbrenner 1977). The macrosystem is the "societal blueprint" for a specific culture or subculture (Bronfenbrenner 1994). Added later, the fifth and last subsystem, the *chronosystem*, considers the physiological changes of the developing child as he or she ages. The chronosystem also encompasses historical events that the child might experience over his or her lifecourse such as the 2009 economic recession (Bronfenbrenner 1994).

While EST was originally formulated with the child's psychological well-being in mind, EST can be applied to many different health outcomes. Given that the risk factors for childhood obesity are multi-level, it is well suited as a framework to organize the multiple factors that influence childhood obesity (Davison and Birch 2001). Schreier and Chen (2013) have used it to understand how socioeconomic status at the family and neighborhood level could influence childhood obesity. EST is ideal for childhood obesity in that it allows for the subsystems to interact. It also recognizes that the child is a contributing force in the dynamic. However, since EST is a framework it does not specify the mechanisms by which the subsystems might influence the child. The Family Stress Model of Economic Hardship and the Risky Families Model are used to inform the mechanisms of interest.

Family Stress Model of Economic Hardship

Developed by Conger and colleagues, the Family Stress Model of Economic Hardship posits that both acute and chronic economic hardship cause economic pressure for parents that can then lead to maladjustment for the child (Conger, Rueter and Conger 2000, Conger et al. 2002). *Economic pressure* reflects the psychological impact people experience by not being able to pay bills and the necessity to forego or cut back on essential items. Conger et al. (2002) think the construct is a more objective measure of economic strain. Economic pressure can subsequently cause emotional distress and negative affect (depressed mood) in caregivers which can lead to aggressive behavior such as conflict or withdrawal with each other (see Figure 3.3). This conflict and withdrawal will then spill over to the child (Conger et al. 2002). Caregivers' anger, aggressiveness, withdrawal, and depressed mood will influence the quality of care and nurturant-involved parenting that a child receives (Conger et al. 2002, McConnell, Breitkreuz and Savage 2011, Newland et al. 2013, Scaramella et al. 2008, Thompson 2014). *Nurturant-involved parenting* is when the parent is supportive, not overly tough, and monitors, disciplines and sets limits for the child. A lack of nurturant-involved parenting can have a negative impact on a *child's adjustment*, defined as internalizing or externalizing behaviors and lower positive adjustment (i.e., personal, social and scholastic competence).

One limitation of the FMS for the proposed dissertation is that the FSM was developed for children and adolescents. As such it might not be appropriate for very young children. In their measure of child adjustment they include scholastic competence which would not apply to very young children. Additionally, the model conceptualizes emotional and behavioral competence under the umbrella of child adjustment. Unlike the Risky Families Model that will be described next they have grouped the two aspects together.

The model assumes that economic hardship affects the child through parenting behaviors. While the model has been tested on caregivers who are not the biological parents of the child, the model does assume two caregivers are present and that part of the effect of economic hardship occurs through the conflict between caregivers. The model might therefore not be generalizable to families headed by one caregiver, e.g., a single female, as is prevalent among low-income families. Furthermore, the impact of economic pressure on parenting might not be through conflict between caregivers but rather by decreasing a parent's time and energy if they have to work multiple jobs.

The model does not include the physiological mechanisms by which low-nurturant parenting could lead to child maladjustment. Not having a responsive caregiver can lead to the dysregulation of a young child's stress response systems (Gunnar and Quevedo 2007). Older children are also physiologically vulnerable to stressors, such as conflict or low-nurturant parenting, since the function and connections of various regions in the brain, such as the prefrontal cortex, are still being formed (Tottenham 2014). These physiological dysregulations and malformations can impede children's emotional and social development, leading to behavioral problems, poor emotional regulation, and cognitive difficulties (Gunnar and Quevedo 2007). Another limitation of the FSM is that it does not include the reciprocal nature of the relationships, although the likelihood is mentioned by the authors. If children are aggressive, hyperactive, prone to crying they can be a cause of stress for parents, thereby increasing the likelihood of parents' emotional distress, depressed mood and conflict.

The model might not be generalizable to all children, such as Hispanic children who form the majority of WIC participants in Los Angeles County. The model has been tested on white children living in the rural Midwest and black children living in an urban or rural area of the Midwest (Conger, Rueter and Conger 2000, Conger et al. 2002), and differences have already been found. When the model was tested on the NH black urban and rural children, the effect of both primary and secondary caregiver depression on parenting was completely mediated by conflict in the caregiver relationship. Among NH white rural children, a direct effect of caregiver depressed mood on parenting was also found (Conger et al. 2002).

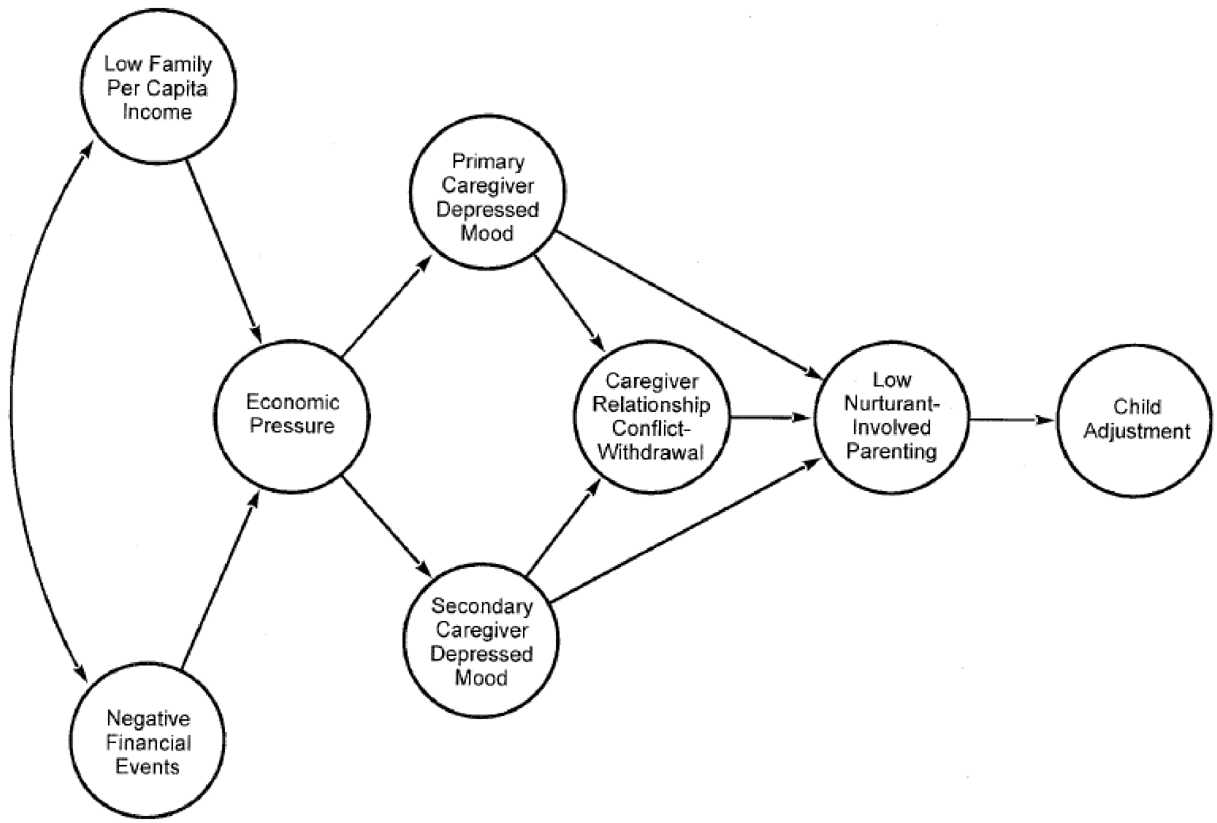


Figure 3.3. Family Stress Model of Economic Hardship

Source: Conger et al. 2002

Risky Families Model

Based on a socioemotional development perspective, the Risky Families Model posits that growing-up in families that are cold, unsupportive or neglectful or ones with a lot of conflict and aggression ("risky families"), can not only have immediate impact on the child but can also lead to poor mental and physical health across the lifecourse by influencing children's biological and psychological development (see Figure 3.4) (Repetti, Taylor and Seeman 2002).

The stressful family environment may perturb the *biological systems* that regulate a child's response to stress. Exposure to the chronic stressor can alter the functioning of the sympathetic-adrenomedullary system, the hypothalamic-pituitary-adrenocortical system (HPA) and serotonergic functioning. For instance, when the HPA axis functions normally, elevated levels of the steroid hormone cortisol shut off the axis through a negative feedback mechanism and cortisol returns to basal levels (Bjorntorp 2001). However, chronic exposure to stress can induce a dysregulation in the HPA axis where it takes longer for the axis to shut down, therefore cortisol levels stay high for a longer period of time (Bjorntorp 2001). Over time, the dysregulation of these stress-response symptoms can lead to allostatic load, the premature wear and tear on the body, which increases an individual's risk of chronic disease.

The exposure to chronic stress can also affect children's ability to *process and control emotions*, leading to internalizing or externalizing problems. These can subsequently influence children's *social competence*, which is their ability to cope in a socially-acceptable manner during difficult interactions with their family or friends. Children who have a hard time controlling their emotions do not have as many friends and are not as well liked (Repetti, Taylor and Seeman 2002). Social competence affects interpersonal relationships and access to social support, both of which can protect against poor health and the adoption of risky health behaviors.

Adolescents raised in risky families are more likely to abuse drugs, alcohol or cigarettes, and to engage in risky sexual behavior. This could be due to insufficient parental supervision, association with peers who engage in risky health behaviors, fewer positive means of coping with stress, and less social support due to their decreased social competence. It can also be a form of self-medication due to the dysregulations of their biological-stress response systems. Smoking, drinking and abusing drugs can alleviate symptoms of serotinergic function dysregulation. These biological, emotional and social mechanisms can lead to poor physical and mental health in adulthood.

The family's *social context* can influence the family environment. Growing up in a poor or low-income family increases the likelihood that a child will be exposed to a risky family environment since these families are generally facing multiple chronic stressors, e.g., poverty, violence, neighborhood disadvantage. Furthermore, individual differences to stressors exist and the impact that the family environment might have may in part be due to genetic susceptibility. One study found that children aged 10 months of insensitive mothers were six times more likely to exhibit externalizing behaviors (i.e., being aggressive or oppositional) two years later if they had a specific allele compared to children who did not have the allele (Bakermans-Kranenburg and van Ijzendoorn 2006).

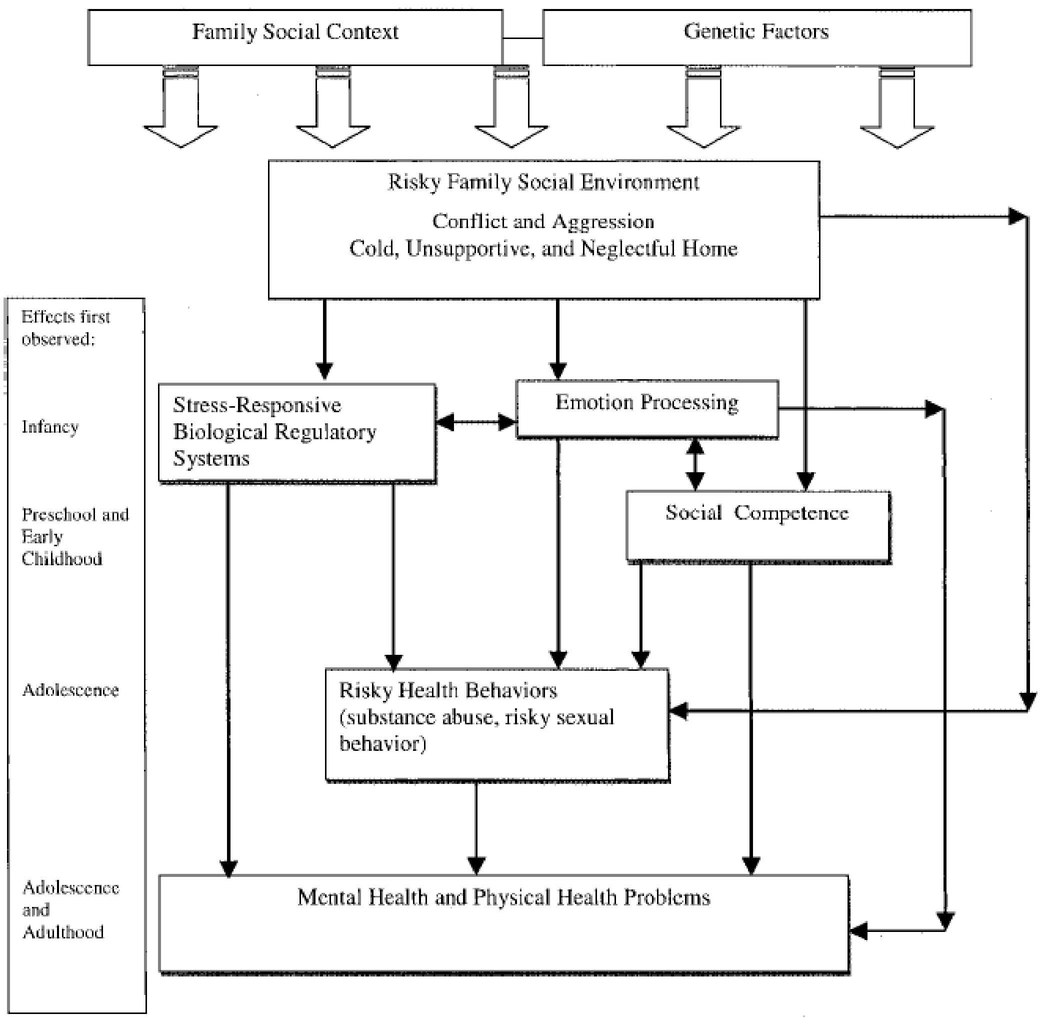


Figure 3.4. The Risky Families Model

Source: Repetti et al. 2002

The Risky Families Model was developed to explain the long-term health effects that can occur after exposure to a poor family environment. As such it does not focus on the health effects or poor health behaviors that can be seen in early childhood. In the case of obesity, the effects of a stressful, or a cold, unsupportive home environment might be seen in early childhood. Insecure attachment, which can be caused by maternal unresponsiveness, at 2 years of age was found to be associated with an increased risk of obesity in children 4.5 years of age (Anderson and Whitaker 2011). Furthermore, a chaotic and stressful home environment was found to be associated with being overweight in preschool-aged children (Lumeng et al. 2014). Lack of emotional support in the home for children aged 5-11 years was found to be positively associated with child's risk of obesity (Garasky et al. 2009).

The model does not mention an unhealthy diet as a risky health behavior. Chronic stress might increase children's energy intake (Adam and Epel 2007, Lumeng et al. 2014, Michels et al. 2015). Approximately 40% of people increase the amount of food they eat when exposed to a chronic stressor or when they feel stressed (Dallman 2010). Although studies have primarily been conducted among adults, a couple of studies have found stress to be associated with emotional eating (eating in the absence of hunger and when feeling stressed, sadness, worry, anger, boredom, or happiness) in adolescents (Jaaskelainen et al. 2014, Nguyen-Rodriguez, Unger and Spruijt-Metz 2009) and that emotional eating is positively associated with weight gain in children (Webber et al. 2009). Among low-income preschool-aged children, Lumeng et al (2014) found that living in chaotic homes was associated with HPA dysregulation and the latter was associated with an increased risk of being overweight. Emotional overeating fully mediated the HPA dysregulation and obesity relationship in preschool-aged boys while reduced satiety responsiveness partially mediated it for girls (Lumeng et al. 2014). Additionally, the authors found that a chaotic home environment was associated with greater food responsiveness (i.e., constantly asking for food and always wanting to eat) which was associated with increased risk of overweight in both boys and girls. Although it had a relatively small sample size, another study found that preschool-aged children who had more externalizing behaviors such as being highly emotional, angry or frustrated were more likely to persistently throw tantrums over food (Agras et al. 2004). These children were also more likely to be overweight a few years later.

Finally, the model does not consider the reciprocity of the relationships. Behavior problems in children can increase parent's distress and depressive symptoms, negligent and/or harsh parenting practices, and parenting-related stress (Bagner et al. 2013, Baker et al. 2003, Gross et al. 2009, Harvey and Metcalfe 2012, Pardini, Fite and Burke 2008, Verhoeven et al. 2010). Some of the studies found a greater effect among preschool-aged children than older children.

Conceptual Framework

Building on the four theories, I hypothesize that severe housing cost burden will influence the risk of childhood obesity through decreased financial resources (Figure 3.5). This economic hardship will increase the risk of stress and depressive symptoms in mothers which will then increase the risk of childhood obesity through children's diet, screen time and stress. The neighborhood and family socioeconomic status will influence both the likelihood of a family experiencing unaffordable housing and the risk of obesity.

From EST's main tenet that the child's subsystems influence the child and that they can interact, the child's family SES and race/ethnicity will determine their likelihood of living in unaffordable housing and these family characteristics will interact with the neighborhood characteristics to influence a child's diet and physical activity levels. Families of low socioeconomic status and of racial/ethnic minority are more likely to live in unaffordable housing (Joint Center for Housing Studies 2014). When a family has a difficult time paying for housing, they will generally live in homes in poor, disadvantaged and unsafe neighborhoods (Joint Center for Housing Studies 2014). Low SES families are more likely to eat low-cost, highly caloric foods and the neighborhoods they live in tend to have more fast food restaurants and less access to affordable, healthy foods (Darmon and Drewnowski 2008, Lovasi et al. 2009, Morland et al.

2002, Schreier and Chen 2013). The neighborhood's social and physical environment—violence, social capital, traffic, safe physical activity resources—will affect how often the child goes outside to play or whether the child stays inside and this can vary by family's race/ethnicity (Carson et al. 2010, Kimbro, Brooks-Gunn and McLanahan 2011). Historical events like the recession might increase risk of childhood obesity through child's access to foods by decreasing household income and changing the neighborhood food environment. However, policy changes like the 2009 WIC voucher change might have increased the availability of healthy foods in the home and have changed the neighborhood food environment.

Additionally, I posit that the reduced financial resources from paying for relatively severe housing cost will affect the child's energy intake through the foods the parents buy. Families living in unaffordable housing allocate less money to expenses such as food (Harkness and Newman 2005). Low-income households severely burdened with housing costs spent 39% less on food than families who lived in affordable housing (Joint Center for Housing Studies 2014).

Drawing on the Family Stress Model of Economic Hardship, I hypothesize that the economic pressure of paying for housing will increase mothers' stress and risk of depression. Parents who feel stressed might be less inclined to cook healthy meals for their children, thereby relying more on fast food for their children (Parks et al. 2012). Stressed parents might also emotionally overeat and children generally like to eat the foods their parents eat (Schreier and Chen 2013, Skinner et al. 1998).

The more stressors low-income parents experience, the less likely they are to limit their children's screen time (i.e., watching TV and playing computer games) (Lampard, Jurkowski and Davison 2013). Watching TV increases the risk of childhood obesity (Dennison, Erb and Jenkins 2002, Rey-Lopez et al. 2008, Swinburn and Shelly 2008). Aside from decreasing physical activity, watching TV increases the likelihood of snacking and increases children's exposure to commercials of sodas and unhealthy foods (Institute of Medicine 2006, Kit, Ogden and Flegal 2014, Marshall et al. 2004, Parvanta et al. 2010, Thomson et al. 2008). Mixed findings exist as to whether playing computer games and using the internet increase the risk of obesity in children (Carvalhal et al. 2007, Rey-Lopez et al. 2008, Swinburn and Shelly 2008)

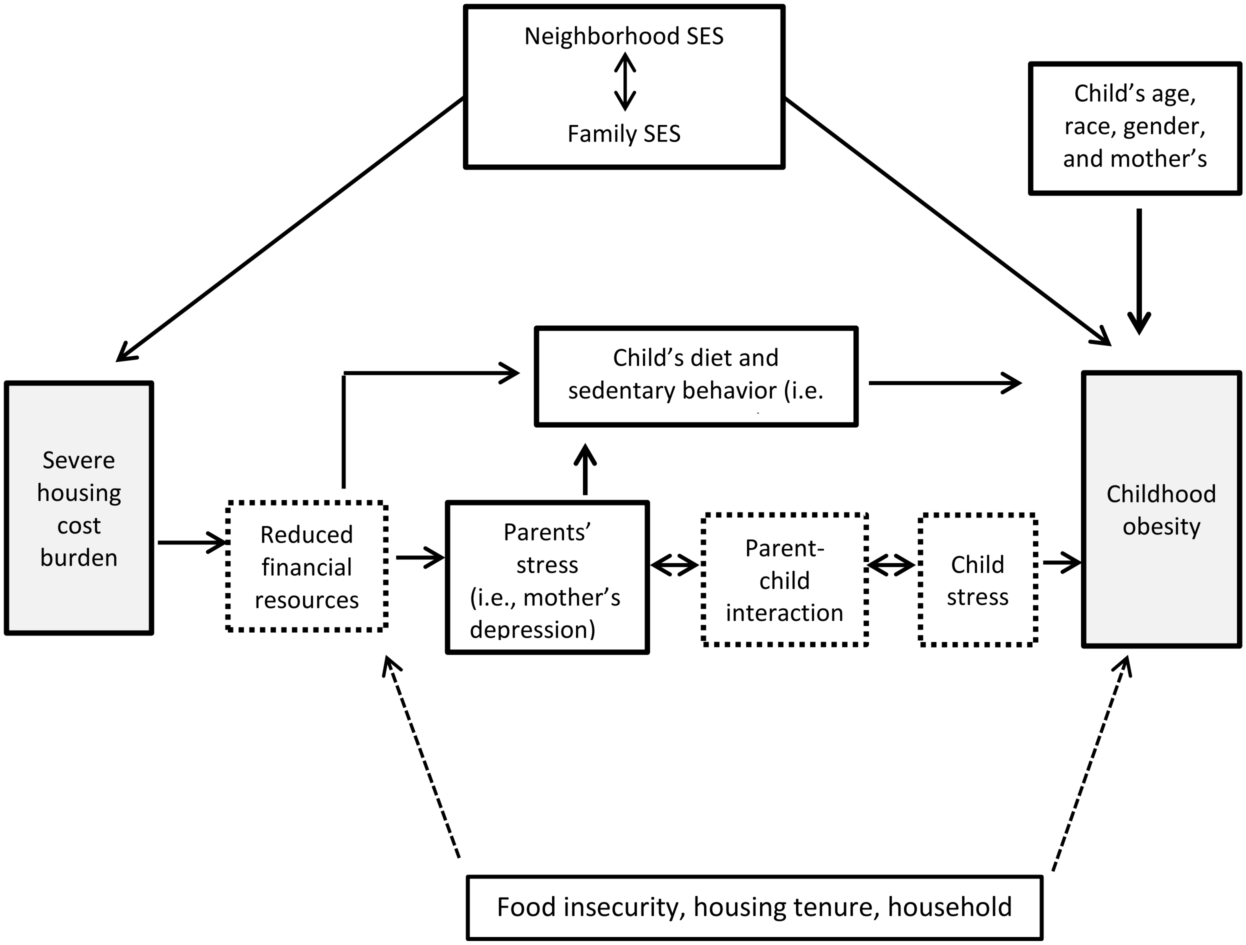
Stress and depression in parents can lead to parents being harsh and unsupportive, although the Family Stress Model hypothesizes that this is through conflict between two caregivers. Low-nurturant parenting can subsequently impede a secure attachment of the young child with his/her primary caregiver. Indeed, studies have found that parental stress is associated with insecure attachment of the child and also with parents' not being sensitive to the child, both of which are associated with increased stress in the child. Insecure attachment and maternal unresponsiveness in infancy and toddlerhood is associated with increased risk of obesity in preschool-aged children and adolescents (Anderson and Whitaker 2011, Anderson et al. 2012). Chronic maternal depression during infancy and preschool years is also positively associated with risk of childhood obesity (Lampard, Franckle and Davison 2014). Additionally, emotional support has been found to protect against obesity in children (Garasky et al. 2009). Although one study found that general family functioning or ineffective parenting style was not associated with obesity (Gibson et al. 2007) and another found that maternal-child relationship quality was also not associated with it.

Drawing on the Risky Families Model, harsh and unsupportive parenting might cause a dysregulation of the child's hypothalamus-pituitary-adrenal (HPA) axis, especially in very young children who are dependent on their caregivers to regulate their biological response to stress (Gunnar and Quevedo 2007, Thompson 2014). The HPA dysregulation can then increase the risk of childhood obesity (Miller et al. 2013). A few studies have found that hypocortisolism (low levels of cortisol or a blunted cortisol response to stress) is associated with overweight and obesity in children (Lumeng et al. 2014, Miller et al. 2013, Ruttle et al. 2013).

Drawing on EST, the conceptual model includes bidirectional arrows to show that the child can influence parent's stress and mental health (in this case, the mother's). Chronic stress not only influences the child's physiology but it can also impede a child's emotional and social development, leading to behavioral problems, poor emotional regulation, and cognitive difficulties (Gunnar and Quevedo 2007). These can subsequently increase a parent's own stress by making it more difficult for the parent to take care of the child. Although not shown in the framework, other bidirectional relationships might exist. Child temperament and food preferences do influence what the child is given to eat. Interactions between the mediators might exist as well. For instance, child's food preferences can be influenced by the marketing on TV.

Household tenure, food insecurity and household size are explored as potential confounders and moderators of the relationship between severe housing cost burden and childhood obesity risk. People who own their own homes have greater wealth than renters and this applies to low-income families even after the economic recession (Braveman et al. 2005, Herbert, McCue and Sanchez-Moyano 2013, Pollack et al. 2007). Additionally, Pollack at al. (2010) found that the association of unaffordable housing with adult health varied by housing tenure with homeowners having better health than renters. Unaffordable housing increases the risk of food insecurity, especially among low-income families (Kirkpatrick and Tarasuk 2011). While findings from studies examining the relationship between food insecurity and childhood obesity are mixed, WIC preschool-aged children living in food insecure households are at greater risk of obesity, although mother's weight and severity of food insecurity moderates the relationship (Eisenmann et al. 2011, Metallinos-Katsaras, Sherry and Kallio 2009, Metallinos-Katsaras, Must and Gorman 2012). The more people living in a household, the more likely it is to be chaotic (Evans 2004) and household chaos has been found to cause hypothalamus-pituitary-adrenal (HPA) axis dysregulation in low-income young children (Lumeng et al. 2014). Furthermore, mothers living in crowded homes are not as responsive to their children (Evans et al. 2010).

Figure 3.5. Conceptual framework of unaffordable housing and childhood obesity



.... Not available in the WIC Survey dataset.

----> Food insecurity, housing tenure and household size are explored as potential confounders and moderators.

CHAPTER 4: Trends in obesity by socioeconomic status among WIC preschool-aged children in Los Angeles County, 2003-2014

Background

The rates of childhood obesity in the U.S. have increased more than three-fold in the last forty years (May et al. 2013). Data from the National Health and Nutrition Examination Surveys show that among boys aged 2-19 years in the U.S., the prevalence of obesity increased from 5.4% in 1976-1980 to 16.7% in 2011-2012 (Ogden et al. 2014). A similar pattern is seen among girls (Ogden et al. 2014). While trends in obesity rates among all children aged 2-19 years have remained relatively stable since 2003, when disaggregated by age group, a statistically significant decrease is observed among children aged 2-5 years: from 13.9% in 2003-2004 to 8.4% in 2011-2012 (Ogden et al. 2014).

Mirroring these trends, obesity rates among the low-income pre-school aged population participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) have also started to decline in recent years (Sekhobo et al. 2013). For example, in Los Angeles County, obesity rates among low-income 4-year-old children participating in WIC reached a peak of 22.4% in 2009 and then decreased to 20.3% in 2011 (Sekhobo et al. 2013). A major legislative change in 2009 affecting the foods offered by the WIC program to participating families (72 C.F.R. § 68966) may be at least partially responsible for the decreasing rates (Federal Register 2007, Sekhobo et al. 2013, WIC 2014). While its direct impact on childhood obesity has yet to be determined, studies have reported that the new food package has had a beneficial impact on the availability of healthier foods in the home and in the neighborhood, on the price of fresh produce, and on the replacement of whole-fat milk with low-fat milk (Andreyeva et al. 2014, Chiasson et al. 2013, Odoms-Young et al. 2014, Whaley et al. 2012, Zenk et al. 2014).

While overall obesity rates have declined in Los Angeles County since 2009, the trends vary by race and ethnicity (Sekhobo et al. 2013) and neighborhood socioeconomic conditions (Chaparro, Wang and Whaley 2013). A recent report showed that obesity rates have continued to climb in the most disadvantaged neighborhoods (Chaparro, Wang and Whaley 2013). It is likely that in these neighborhoods, WIC-participating families are unable to reap the benefits of WIC participation (nutrition education and food vouchers) because of neighborhood-level chronic stressors and major household-level stressors such as low income and unaffordable housing.

Disadvantaged neighborhoods are generally defined by a low median household income, or by a high proportion of residents with low educational attainment. Living in disadvantaged neighborhoods may increase the likelihood of a child developing obesity through the inaccessibility of healthy foods or the increased accessibility of unhealthy foods. It is documented that disadvantaged neighborhoods often have fewer stores that sell affordable fresh produce, more small corner stores that sell unhealthy, energy-dense processed foods, and fewer safe recreational areas where children can play (Lovasi et al. 2009, Moore and Diez Roux 2006, Morland et al. 2002, Singh, Siahpush and Kogan 2010a).

The Great Recession that occurred from 2008 to 2009 only aggravated the situation for minority and low-income families as they experienced higher rates of unemployment and greater declines in their income and wealth (Joint Center for Housing Studies 2011, Ng, Slining and Popkin 2014). Increased rates of childhood obesity among minority children can be partially attributed to socioeconomic, and cultural factors (Caprio et al. 2008). A family's income can influence the risk of a child developing obesity by shaping diet and physical activity behaviors, and through economic resources which provide access to healthy foods and the ability to live in a safe neighborhood with access to stores that carry fresh produce, parks and recreational areas (Braveman, Egerter and Barclay 2011, Schreier and Chen 2013). Low-income households are more likely to have unhealthy diets, live in poor and unsafe neighborhoods where fresh food and possibilities for exercise are less accessible (Adler and Stewart 2010a, Braveman, Egerter and Barclay 2011, Lovasi et al. 2009). The effect on obesity of this differential access to resources is apparent among vulnerable low socioeconomic status (SES) children. In 2011, 14.2% of preschool-aged children in families ≤ 50% of the federal poverty level (FPL) were obese compared to 11.8% of preschool-aged children in families with 151-185% FPL (CDC 2014).

Parents' education also determines children's access to resources and quality of life. Children living in more educated families are less likely to be influenced by factors such as an economic recession not only because higher educated individuals have a greater capacity for weathering poor labor market conditions (Cutler, Huang and Lleras-Muney 2015) but education can also protect against obesity through health literacy, improved health behaviors such as healthier diets and physical activity (Chandola et al. 2006, Cutler and Lleras-Muney 2006, Kenkel 1991, Lleras-Muney 2005), and less chaotic home environments (Strauss and Knight 1999). Furthermore, higher educated individuals might be more likely to take advantage of services provided by obesity-prevention programs.

Understanding the impact of these socioeconomic characteristics on childhood obesity during significant economic, policy, and environmental changes is critical for building a comprehensive framework for investigating the etiology of childhood obesity and designing effective population level interventions. Using data gathered from participants of the Special Supplemental Nutrition Program for Women, Infants and Children (WIC), this descriptive study examines the trends in obesity among preschool-aged WIC children in Los Angeles County from 2003 to 2014 by household and neighborhood socioeconomic characteristics and it attempts to answer the following research questions: *What are the trends in childhood obesity in the Los Angeles County WIC-participating population from 2003 to 2014? How do these trends vary according to household and neighborhood socioeconomic characteristics? Do different* *patterns in these trends emerge among children of different ages and of different race/ethnicities?*

Methods

Participants

The study population consists of children aged 2-5 years participating in WIC in Los Angeles County during the years 2003 to 2014. Pregnant, breastfeeding, and postpartum women, infants, and children less than five years old who are low-income (≤185% FPL) and at nutritional risk are eligible to participate in WIC. "Nutritional risk" is defined by Section 17(b)(8) of the Child Nutrition Act of 1966 as amended, with the broadest criteria being "conditions that predispose persons to inadequate nutritional patterns or nutritionally related medical conditions" (USDA, 2011, p. 2). Nutritional risk is determined during the enrollment process by WIC staff and includes not meeting dietary recommendations such as not drinking enough milk or not eating enough fruits and vegetables (S Whaley, personal communication). In Los Angeles County, over half of all children ages one to five participate in WIC (LA WIC Data, n.d.).

WIC administrative data were used for this study. The data are maintained by the State of California WIC Program. Initiated in 2003 by Public Health Foundation Enterprises-WIC (PHFE WIC), the largest local WIC agency in the country, and funded by First 5 LA through a research partnership, the WIC Data Mining Project acquires and maintains WIC administrative data for all seven local WIC agencies in Los Angeles County through agreements with the State of California (www.phfewic.org). This unique database maintains WIC participant records for every year since 2003; the data include sociodemographic and anthropometric information on the participants.

For child participants, height and weight data are obtained every six months by WIC staff who are trained to follow a standardized protocol for measuring height and weight. Children's height is measured using wall-mounted stadiometers (Model PE-WM-60-76; Prospective

Enterprises, Portage, MI) and weight is measured using calibrated beam scales (Health-O-Meter 402LB; Prospective Enterprises, Portage, MI). These measurements are made during clinic visits. In the event that a child's height and weight measurements were taken by a health-care provider within 60 days of his/her WIC visit, the healthcare provider's measurements can be used (Crespi et al. 2012); approximately 20% of measurements are obtained this way. Height and weight measurements obtained by PHFE-WIC staff in Los Angeles County on children aged 2-5 years have been found to have high validity (Crespi et al. 2012).

In addition, WIC participants' addresses have been geocoded at the census tract level by the Los Angeles County Internal Services Department (ISD). In 2012, ISD began using 2010 census tract boundaries. To obtain neighborhood socioeconomic information on the participants, we linked the Census Bureau's American Community Survey (ACS) data using the participants' census tracts. Five-year ACS estimates from 2005-09 were linked to measurements from 2003 to 2009 and five-year estimates from 2010-14 were linked to measurements from 2010 to 2014.

Since children at very young ages grow rapidly and are therefore developmentally and nutritionally different at every age (Tanner 1990), we examined the trends in obesity separately at each child's age (2 years, 3 years, and 4 years) and used the first measurement if a child was weighed and measured more than once in a calendar year. Children who were missing data on any variable were excluded from the analyses. We started with a sample size of 2,547,126 observations and excluded 19.8% because they were missing relevant information such as census tract or a covariate, or because they were not a child's first observation in a calendar year. The final sample size was 2,042,767 measurements from 749,904 2-year-old children, 717,583 3-year-old children, and 575,280 4-year-old children. The same child could be included in each of the samples.

Variables

The outcome, child's obesity status, was defined as having a BMI ≥ 95th percentile of CDC's gender- and age-specific growth reference values (Kuczmarski et al. 2002).

The main independent variables were household- and neighborhood-level socioeconomic characteristics of the participants which represented different facets of a child's socioeconomic status (SES). *Household income*, which is considered an indicator of a child's standard of living (Duncan et al. 2002), was operationalized as a percentage of the federal poverty level (FPL). It includes income from all sources such as wages, unemployment compensation, social security benefits, State Disability Insurance, public assistance, and child support. Income is assessed at each WIC certification or re-certification appointment and proof of income (e.g., pay stubs) must be shown. This measure was categorized as ≤50% FPL, 51-100% FPL%, 101-135% FPL, and 136-185% FPL. *Household education* which generally indicates parents' occupation, economic potential, knowledge, and skills (Adler and Newman 2002, Duncan et al. 2002) was operationalized as the highest grade completed by the caregiver who enrolled the child in WIC, and was categorized as less than high school, high school, some college, college or more.

The neighborhood level variables were *median household income and unaffordable housing* and the data were obtained by the Census Bureau's American Community Survey (ACS). These variables provide an indication of environmental resources available to residents. Median household income represents the 5-year estimate of the median household income of residents living in the child's census tract and was categorized according to the quartiles of the distribution among WIC participants (≤$ 32,738; $32,739-40,278; $40,279-51,534; ≥51,535). It should be noted that $55,870 (in 2014 dollars) is the median income in Los Angeles County (U.S. Census Bureau 2016) suggesting that many of these are still disadvantaged neighborhoods. *Neighborhood unaffordable housing* represents the 5-year estimate of the percentage of residents living in the child's census tract who live in unaffordable housing (i.e., spending > 30% of income on housing-related costs), and was categorized as ≤ 40%, 40.1-55.0%, 55.1-70.0%, and ≥ 70.1% of residents. Since median household income does not reflect the extent to which people experience economic hardship, trends in obesity were examined by this measure of housing burden.

Given that the relationship of SES with obesity varies by race/ethnicity, we also examined the trends by household race/ethnicity (Ogden et al. 2010b, Wang and Zhang 2006), which is operationalized as the race/ethnicity of the child's caregiver and was categorized as Hispanic, Non-Hispanic (NH) white, NH black and NH Asian. The trends in obesity over time were examined by calendar year which was the year of the child's clinic visit when weight and height measurements were obtained.

Statistical Analysis

Univariate analysis was used to examine participants' sociodemographic characteristics and bivariate analysis, specifically chi-square tests, was used to assess the relationship between childhood obesity and each of the four SES measures. To illustrate how trends in obesity might be different by SES, absolute disparities, defined as the difference in the prevalence of obesity between the lowest and highest SES group, were examined. Bivariate tests for statistical significance were based on a p-value < 0.05. Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

Results

Aggregating across all years, the sample had approximately equal percentages of girls and boys (see Table 4.1). Obesity prevalence increased with age, with 16.4%, 19.0% and 20.5% of 2-, 3-, and 4-year-old children, respectively, obese.

Across all three age groups, approximately 85% of children had caregivers who were Hispanic, and more than 70% of children lived in poor households (≤100% FPL), with a quarter of them living in extremely poor households (≤50% FPL) (Table 4.1). More than half of the children had caregivers who did not graduate from high school and nearly a third had caregivers who had a high-school degree. Only three percent of caregivers had a college degree or more (Table 4.1).

Since quartiles were used, a quarter of children lived in neighborhoods that had median household incomes less than or equal to $32,738, and a quarter lived in neighborhoods that had median household incomes at least $51,535 (Table 4.1). Across all three ages, the majority of children (≈ 88%) lived in neighborhoods that had 40 to 70% of residents living in unaffordable housing (Table 4.1).

Table 4.1. Sociodemographic characteristics of WIC-participating children by age: Los Angeles County, 2003-2014

	2 years N=749,904 Mean (SD) or %	**3 years** N=717,583 Mean (SD) or %	**4 years** N=575,280 Mean (SD) or %
Gender (female)	49.0	49.0	48.9
% obese	16.4	19.0	20.5
Household race/ethnicity			
NH white	3.8***	3.6***	3.6***
NH black	7.4	7.1	6.7
NH Asian	4.0	3.8	3.8
Hispanic	84.9	85.5	85.9
Household income			
≤ 50% FPL	26.5***	26.1***	25.7***
50.1 – 100.0% FPL	45.4	46.0	46.7
100.1 – 133.0% FPL	16.0	16.0	15.9
133.1 – 185.0% FPL	12.0	11.9	11.6
Household education			
< high school	54.7***	56.0***	57.3***
High school	32.8	32.2	31.3
Some college	9.4	8.9	8.6
College or more	3.2	3.0	2.8
Neighborhood Median Household Income			
≤ $ 32,738	25.0	25.1	25.2
$32,739 - 40,278	24.8	25.0	25.1
$40,279 - 51,534	25.0	25.0	25.1
≥ $51,535	25.3	25.0	24.6
Neighborhood Unaffordable Housing†			
≥70.1%	7.2***	7.3***	7.3***
55.1-70.0%	49.8	50.0	50.2
40.1-55.0%	38.7	38.5	38.4
≤ 40.0%	4.3	4.2	4.1

Chi-Square test of differences: *p-value <0.05; **<0.01; ***<0.001
Obesity is having a BMI ≥ 95th percentile of CDC's gender- and age-specific growth reference values
NH = Non-Hispanic; FPL = Federal poverty level.
†Percent of residents living in unaffordable housing (i.e., spending > 30% of income on housing costs).

Children's census tracts

The children lived in 2,643 census tracts in Los Angeles County (see Table 4.2). The tracts had a mean population size of approximately 4,560 people and a median household income of about $59,000 (Table 4.2). More than 50% of the census tracts had median incomes above ≥ $51,535. Approximately 16% of residents lived below the federal poverty level. There were approximately 1,600 housing units in the census tracts and the median gross rent, which includes the monthly cost of utilities and fuels, was $1,223. The average rent represented nearly 35% of residents' income. More than 80% of the census tracts had 40-70% of residents living in unaffordable housing (Table 4.2).

Table 4.2. Characteristics of the census tracts in which the sample of WIC-participating children lived: Los Angeles County, 2003-2014

	Mean (SD) or % N=2,643
Population size	4,559 (1,769)
Median household income	$59,342 (28,897)
Neighborhood median household income	
≤ $ 32,738	14.23
$32,739 - 40,278	14.83
$40,279 - 51,534	18.24
≥ $51,535	52.71
Percentage in poverty	16.4 (12.1)
Total housing units	1,599 (752)
Median gross rent	$1,223 (377)
Rent as percent of income	34.9 (8.0)
Neighborhood unaffordable housing†	
≥70.1%	3.9
55.1-70.0%	33.1
40.1-55.0%	49.1
≤ 40.0%	13.9

†Percent of residents living in unaffordable housing (i.e., spending > 30% of income on housing costs).

Childhood obesity by race/ethnicity and household- and neighborhood-level SES

For all three age groups, when examined by household race/ethnicity, obesity rates were higher among Hispanics, then NH whites, NH blacks, and Asians (see Table 4.3).

When examined by the household- and neighborhood-level socioeconomic indicators, a statistically significant negative dose-response relationship existed with early childhood obesity (Table 4.3), with higher obesity rates among children living in the lowest SES families or neighborhoods and lower rates among children living in the highest SES families or neighborhoods. Interestingly, the magnitude of the difference in obesity rates between the highest and lowest SES families and neighborhoods varied by SES indicator. For household income, the difference also decreased with child's age. Among 2-year-old children, the absolute difference in obesity rates between children living in families ≤50% FPL and children living in families at 133.1 – 185.0% FPL was 2.1 percentage points. For 3- and 4-year-old children, it was 1.6 and 1.2 percentage points, respectively.

In contrast, the difference in obesity rates between children in the highest and lowest SES families did not vary by age when household education was used as the indicator of socioeconomic status (5.5 percentage points) (Table 4.3). For neighborhood median household income, the difference in obesity rates between children living in the lowest SES neighborhoods and children living in the highest SES neighborhoods was about 2.7 percentage points across all three age groups. For neighborhood unaffordable housing, the difference in obesity rates between children living in neighborhoods with at least 70% of residents experiencing unaffordable housing and children living in neighborhoods with not more than 40% of residents experiencing unaffordable housing was 2.5 percentage points for 2-year-old children and 3.0 percentage points for 3- and 4-year-old children.

Table 4.3. Prevalence of obesity among WIC-participating children by age, race/ethnicity, and the four socioeconomic indicators: Los Angeles County, 2003-2014

	2 years N=749,904 %	**3 years** N=717,583 %	**4 years** N=575,280 %
Household race/ethnicity			
NH white	11.4***	13.1***	14.2***
NH black	10.2	12.0	13.7
NH Asian	9.74	11.7	12.1
Hispanic	17.4	20.1	21.6
Household income			
≤ 50% FPL	17.2***	19.3***	20.5***
50.1 – 100.0% FPL	16.4	19.2	20.9
100.1 – 133.0% FPL	16.0	18.6	20.1
133.1 – 185.0% FPL	15.1	17.7	19.3
Household education			
< high school	17.3***	19.9***	21.5***
High school	16.0	18.3	19.6
Some college	14.4	16.9	18.5
College or more	11.7	14.4	15.9
Neighborhood Median Household Income			
≤ $ 32,738	17.6***	20.2***	21.6***
$32,739 - 40,278	17.0	19.6	21.3
$40,279 - 51,534	16.1	18.6	20.2
≥ $51,535	15.0	17.4	18.9
Neighborhood Unaffordable Housing†			
≥70.1%	17.2***	19.9***	21.3***
55.1-70.0%	16.8	19.4	20.9
40.1-55.0%	15.9	18.4	20.0
≤ 40.0%	14.8	16.9	18.3

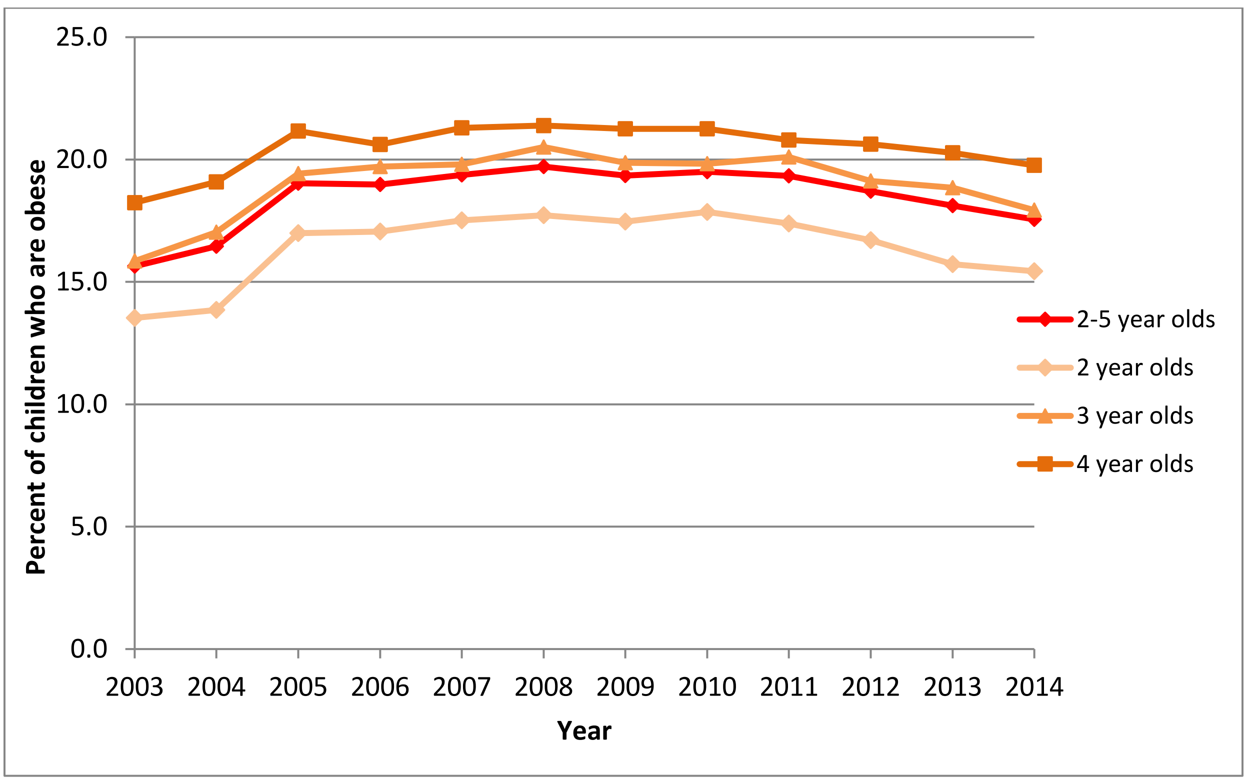
Obesity is having a BMI ≥ 95th percentile of CDC's gender- and age-specific growth reference values
NH=Non-Hispanic; FPL = Federal poverty level.
Chi-square test * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
†Percent of residents living in unaffordable housing (i.e., spending > 30% of income on housing costs).

Secular trends in obesity

For all three age groups, obesity rates increased sharply from 2003 to 2005, remained relatively constant until 2010 for 2- and 4-year old children and until 2011 for 3-year-old children (Figure 4.1). Since then, obesity rates decreased among all three age groups with a slower decline among 4-year-old children. While obesity rates declined since 2010/2011, the 2014 rates were still higher than 2003 levels for all three age groups. Between 2003 and 2014, 2-year-old children experienced the greatest overall increase in obesity (2.5 percentage points) compared to 3- and 4-year-old children (2.1 and 1.5 percentage points, respectively).

Among 2-year-old children, obesity prevalence was 13.5% in 2003, reached a peak of 17.9% in 2010, and then decreased to 15.4% in 2014. Among 3-year-old children, obesity prevalence was 15.9% in 2003, reached a peak of 20.5% in 2008, remained relatively constant until 2011 and then decreased to 17.9% in 2014. Among 4-year-old children, obesity prevalence was 18.2% in 2003, increased to 21.4% in 2008, remained relatively stable until 2010 and then decreased to 19.8% in 2014.

Figure 4.1. Trends in obesity prevalence among WIC-participating children by age: Los Angeles County, 2003-2014



Trends in obesity by household income

The secular trends in obesity rates varied by household income and child's age (Figures 4.2-4). These age differences in trends could be partially attributed to differing rates of decrease in obesity rates beginning in 2010 among the children. Among 2-year-old children, obesity rates among the four income groups increased until 2006, remained relatively constant until 2010, and then decreased at similar rates (Figure 4.2). Among 3-year-old children, obesity rates among the four income groups increased until 2008, and then decreased with steeper rates among the higher income children (Figure 4.3). Among 4-year-old children, obesity rates among the four income groups increased until 2007, and then decreased slowly, although relatively steeper rates were observed among children in the highest income families (Figure 4.3).

Among 2-year-old children of all four income groups, 2014 obesity rates were still not back to 2003 levels (Figure 4.2). However, among 3-year-old children, the 2014 obesity rates among the highest income group were approximately back to 2003 estimates (Figure 4.3). Among 4-year-old children, obesity rates among the two highest incomes groups were approximately back to 2003 estimates whereas obesity rates increased among the lower income groups (Figure 4.4). These differing patterns resulted in the absolute disparities in obesity by household income — the difference in obesity rates between the highest income group and the lowest income group—remaining relatively constant between 2003 and 2014 for 2-year-old children (2.0 percentage points) and increasing for 3- and 4-year-old children (from 0.7 to 2.9 and from 0.3 to 2.1 percentage points for 3- and 4-year-old, respectively).

These trends in obesity by household income varied by race/ethnicity. Among Hispanic children aged 2-5 years, obesity rates among children of all income groups increased until 2005, remained relatively constant until 2011, and then decreased (Figure 4.5). Hispanic children in all income groups experienced an overall increase in obesity between 2003 and 2014. Among the NH white and NH black children, obesity rates among children of most income groups increased until 2007/2008, and then decreased (Figure 4.5). However, there was much variation. Among

Asians in the lowest income groups, obesity rates increased until 2006 and then decreased (Figure 4.5). Obesity rates for Asian children in the 3 higher income groups remained relatively constant until 2009 and then decreased at varying rates. These differing racial/ethnic patterns resulted in the absolute disparities in obesity by household income increasing between 2003 and 2014 among Hispanics (1.7 to 2.2 percentage points), NH whites (1.3 to 3.7), and NH blacks (-1.0 to 1.8), and decreasing among Asians (3.1 to 2.0).

Figure 4.2. Trends in obesity by household income among WIC-participating children aged 2 years: Los Angeles County, 2003-14

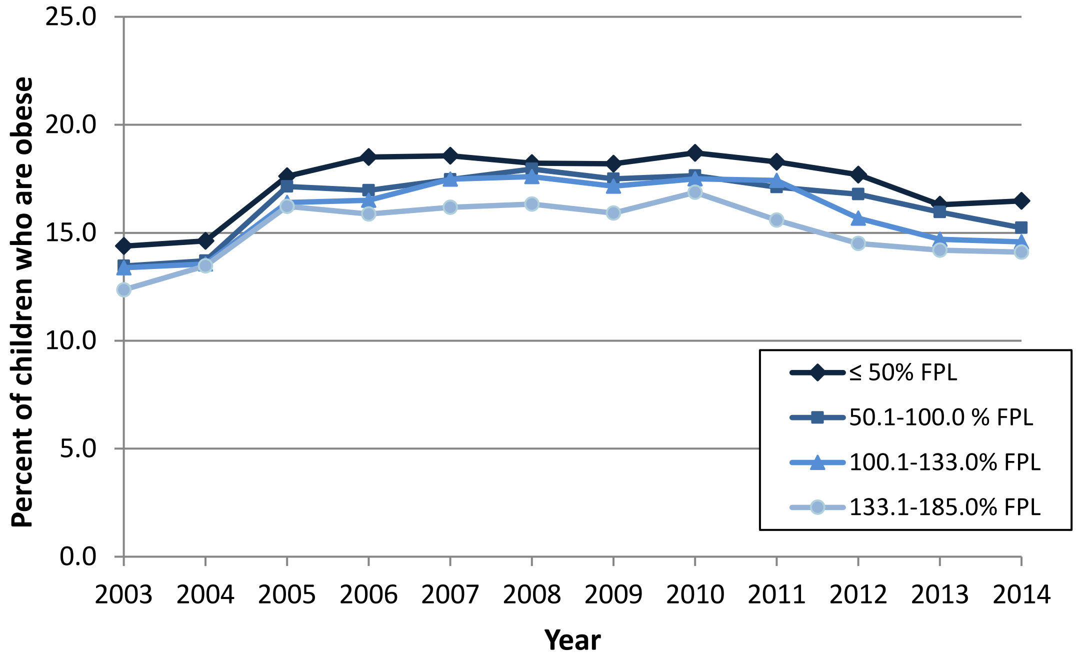


Figure 4.3. Trends in obesity by household income among WIC-participating children aged 3 years: Los Angeles County, 2003-14

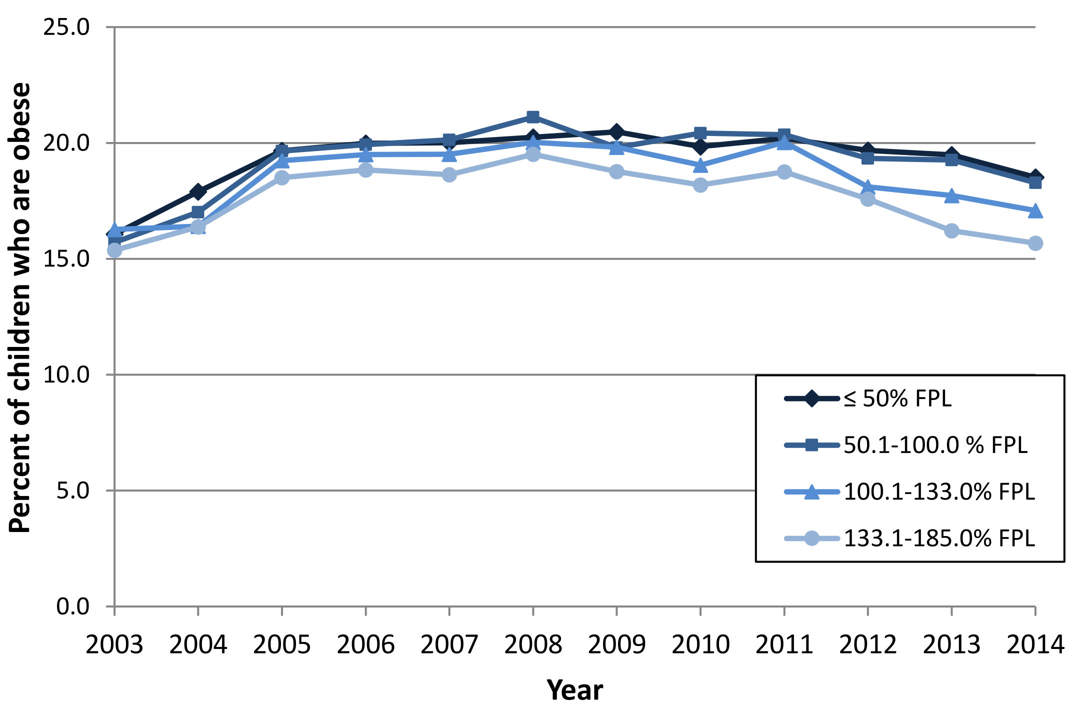


Figure 4.4. Trends in obesity by household income among WIC-participating children aged 4 years: Los Angeles County, 2003-14

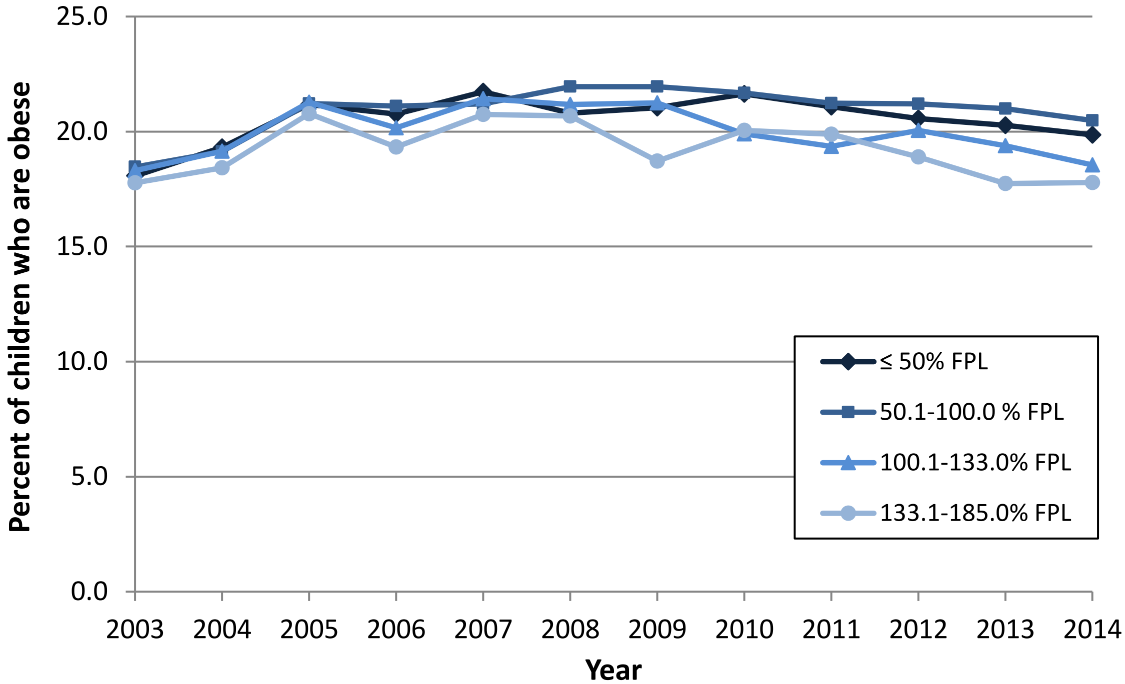
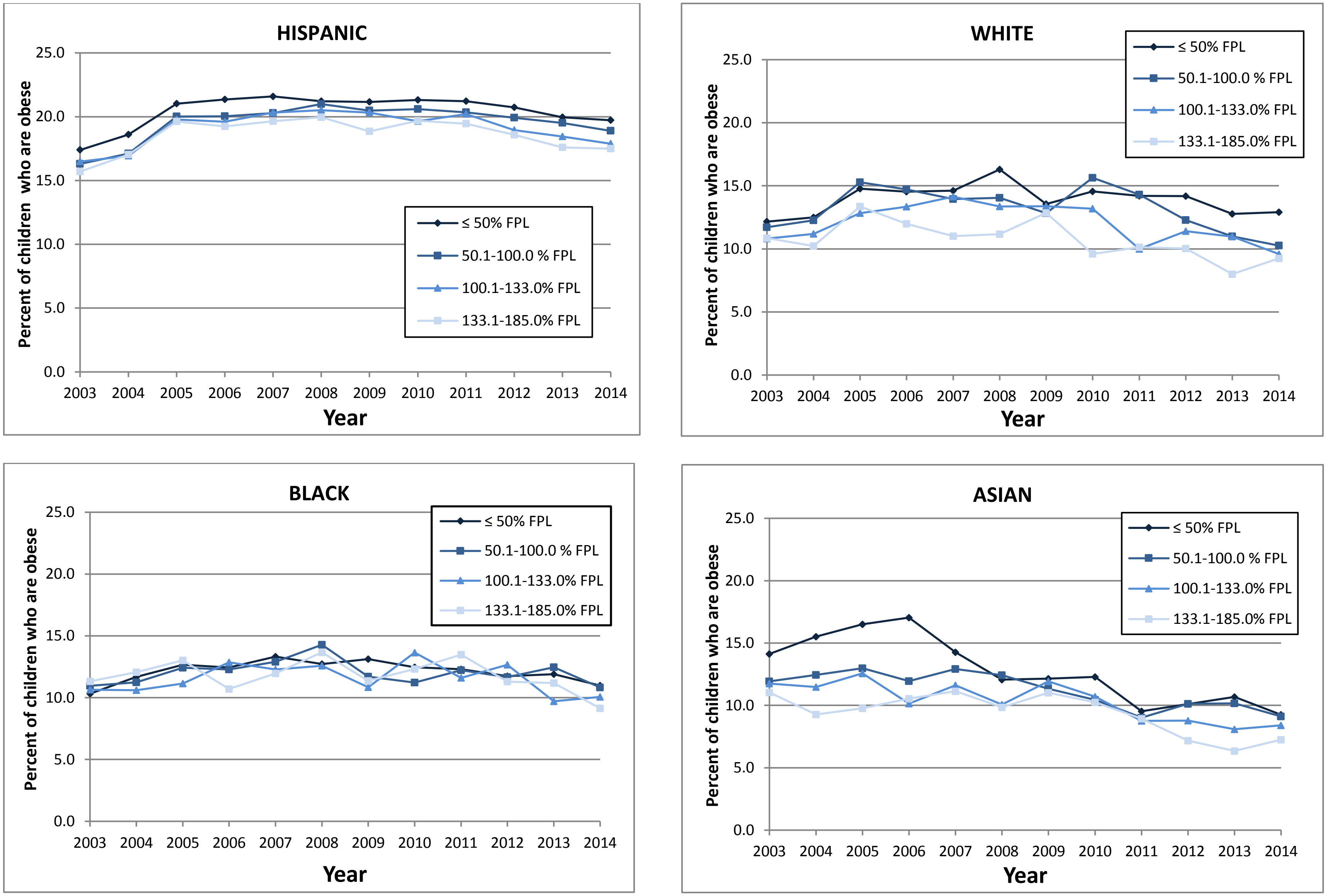


Figure 4.5. Trends in obesity by household income and race/ethnicity among WIC-participating children aged 2-5 years, 2003-14



Trends in obesity by household education

The socioeconomic gradient in obesity was much more distinct with education than it was with household income. While obesity rates were higher among the older children, similar secular trends in obesity by household education existed among 2- and 3-year-old children (Figures 4.6-7). Obesity rates among 2- and 3-year-old children in the three lower education households increased until 2005, remained relatively constant until 2010/2011 and then decreased. More variability existed in obesity rates among children in households with at least a college education, with an overall increasing trend until 2008/2009 and then a steeper decrease. Obesity rates among 4-year-old children in all four education groups increased until 2005. Among 4-year-old children in the lower-educated households, obesity rates remained relatively constant until 2012/2013 and then decreased. For children in the college-educated households, obesity rates continued to increase until 2008 and then decreased at a steeper rate than for the three lower-education households (Figure 4.8).

Between 2003 and 2014, overall obesity rates among most children increased. However, differences existed by household education level and age. In 2014, obesity rates among 2- and 4-year-old children in the highest-educated households were back to 2003 rates. However, 2014 obesity rates among 2-year-old children in the three lower education groups were more than 2 percentage points higher than in 2003, and among 4-year-old children in the two lower education groups 2014 obesity rates were about 2 percentage points higher than in 2003. In 2014, obesity rates among 3-year-old children in the two lower education groups were 2.7 percentage points higher than in 2003, while obesity rates among 3-year-old children for the two higher education groups were 1-2 percentage points higher.

The trends resulted in the absolute disparities in obesity by household education— the difference in obesity rates between the highest education group and the lowest education group—increasing between 2003 and 2014 for all three age groups (from 3.5 to 6.0 for 2-year-old children, from 4.6 to 5.5 for 3-year-old children and from 3.7 to 6.4 for 4-year-old children).

Interestingly, absolute disparities did not increase substantially for 3-year-old children. Furthermore, contrary to income, education disparities existed in 2003.

These trends in obesity rates by household education varied by race/ethnicity (Figure 4.9). Among children aged 2-5 years, obesity rates among most education groups for Hispanics, NH blacks and NH whites increased until 2008/09 and then decreased until 2014. Obesity rates among Asians reached a peak in 2005 and then subsequently decreased. The overall change in obesity rates between 2003 and 2014 for the four education categories was very small among NH blacks, and decreased substantially among NH Asians. Obesity rates among NH white children in the highest-educated households decreased between 2003 and 2014 more than for the lower-educated households. Among Hispanic children, obesity rates for all four groups increased between 2003 and 2014 with those in the lowest groups experiencing a greater increase. Hence the absolute disparities in obesity by education widened between 2003 and 2014 for Hispanics (2.5 to 4.2 percentage points) and NH whites (1.9 to 4.3), and remained relatively constant for NH blacks (-.8 to -.8) and Asians (2.3 to 2.0).

Figure 4.6. Trends in obesity by household education among WIC-participating children aged 2 years: Los Angeles County, 2003-14

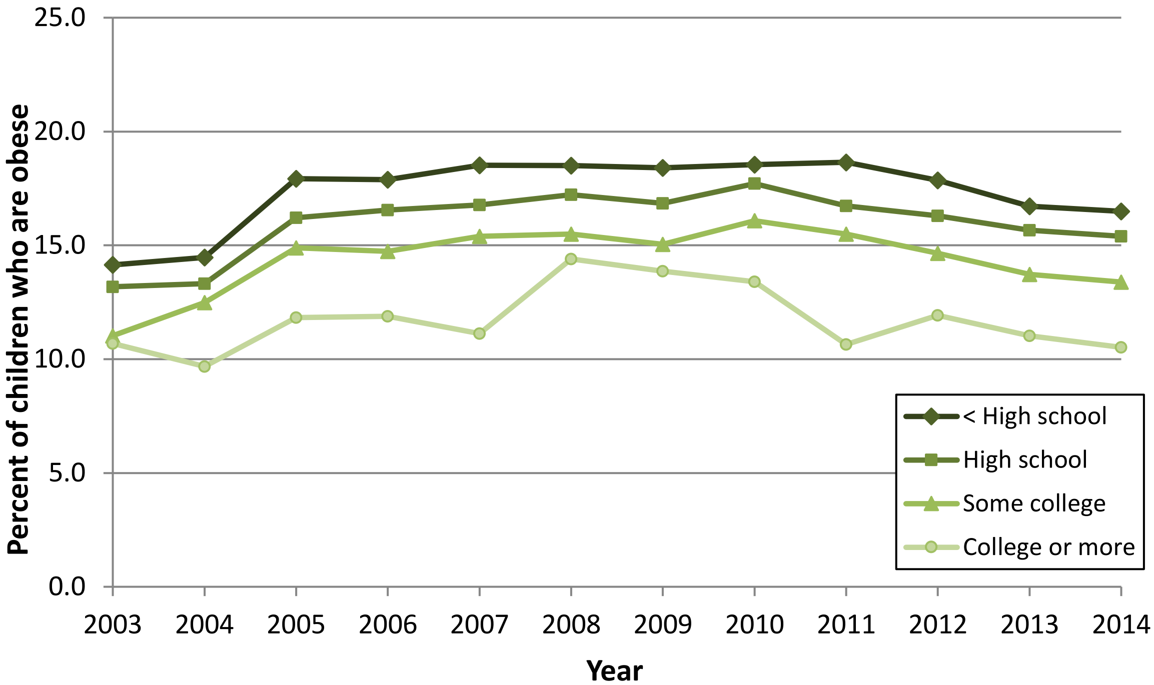


Figure 4.7. Trends in obesity by household education among WIC-participating children aged 3 years: Los Angeles County, 2003-14

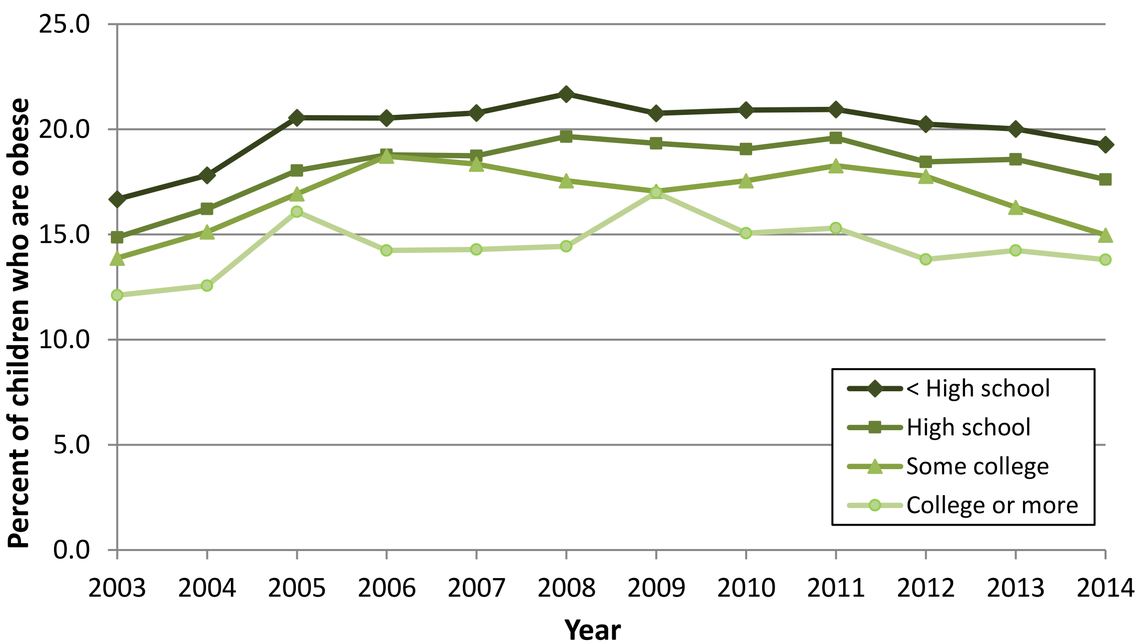


Figure 4.8. Trends in obesity by household education among WIC-participating children aged 4 years: Los Angeles County, 2003-14

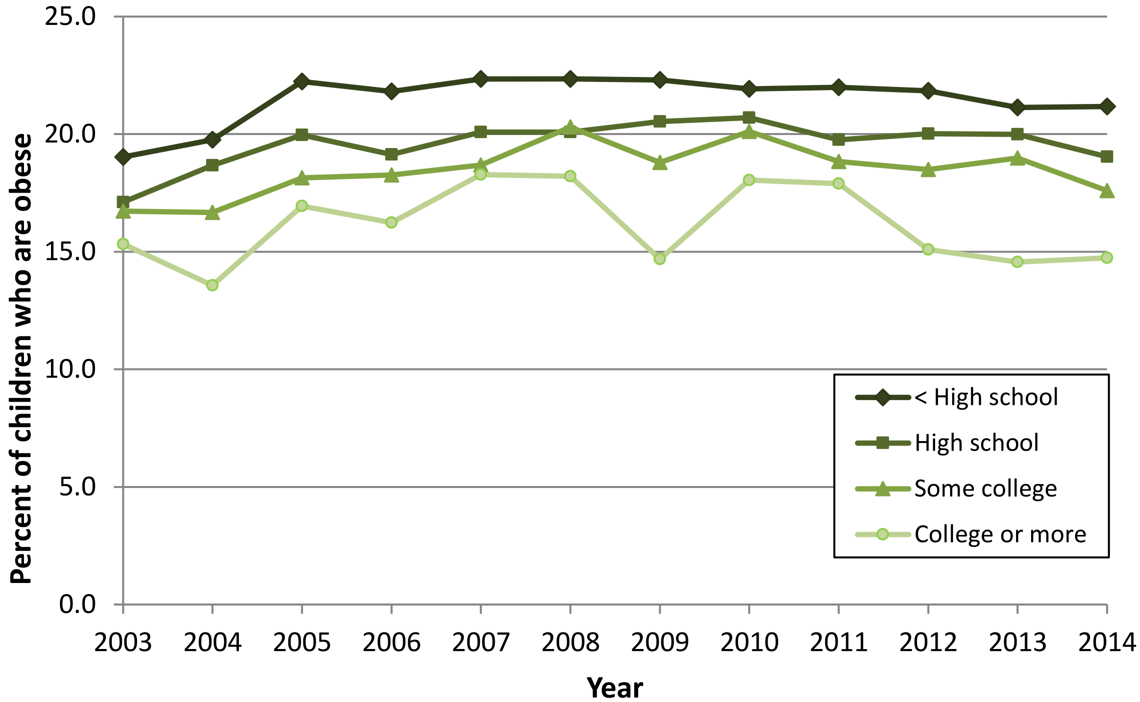
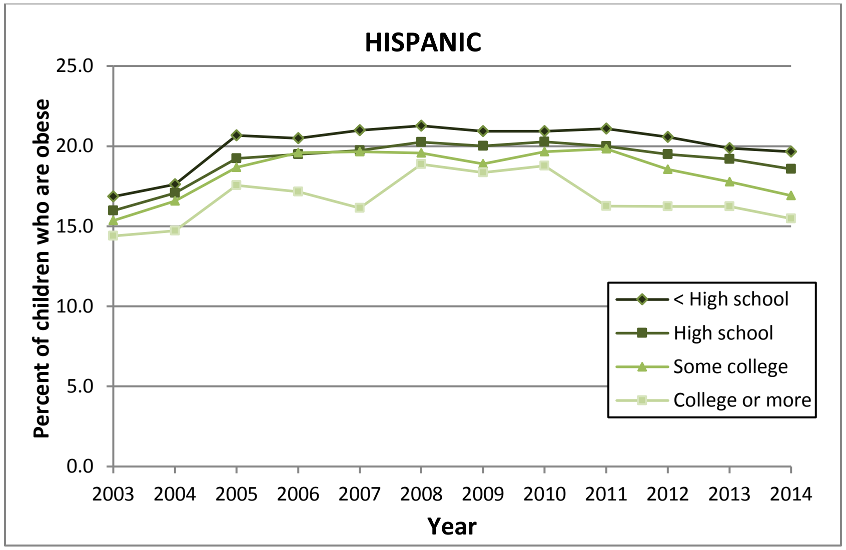
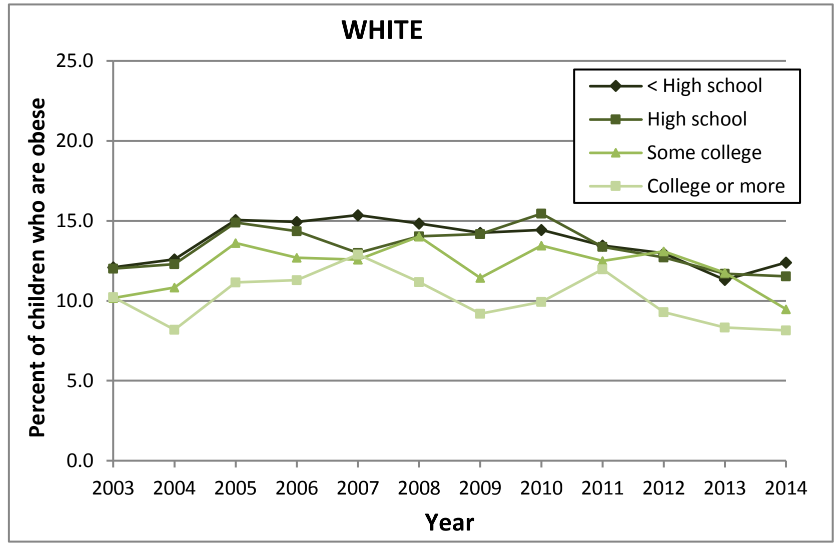
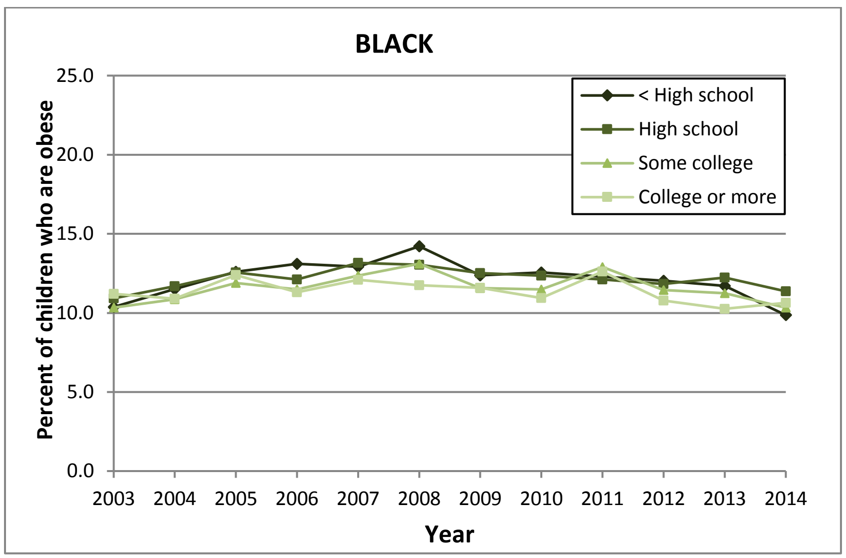
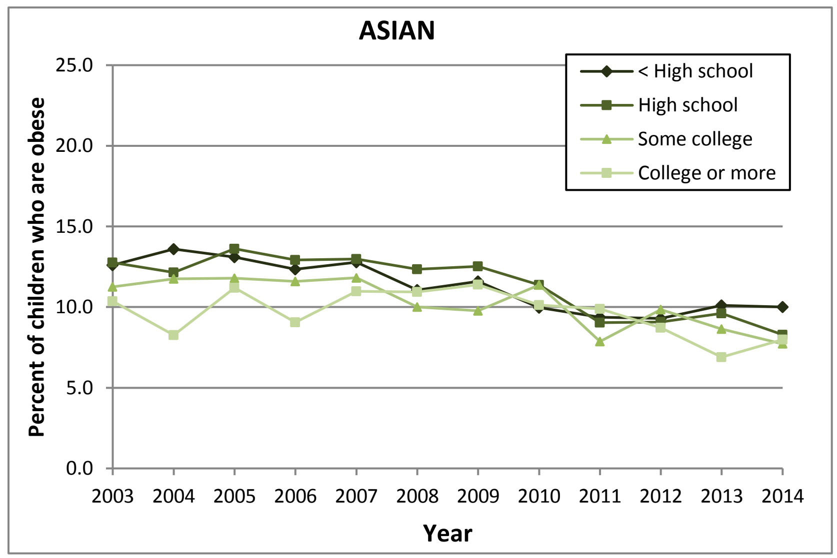


Figure 4.9. Trends in obesity by household education and race/ethnicity among WIC-participating children aged 2-5 years, 2003-14









Trends in obesity by neighborhood median household income

The trends in obesity by neighborhood median household income varied by child's age (Figures 4.10-12). Among 2- and 3-year old children, obesity rates for children in most neighborhoods increased until 2008 and then decreased at similar rates (Figures 4.10-11). Among 3-year-old children in the highest income neighborhoods, obesity rates remained relatively stable after the initial increase in 2005 until a drop in 2013. Among 4-year old children, obesity rates increased until 2008 (with a slower rate of increase from 2005-08), remained relatively constant until 2010, and then decreased (Figure 4.12). The decrease among 4-year-old children in the highest-income neighborhoods was at a much slower rate compared to the other neighborhoods.

Even though obesity rates decreased since 2008, 2014 obesity rates for most neighborhoods were still not back to 2003 rates. Among 2-year-old children, 2014 obesity rates were 2.7 percentage points higher among children living in the second highest income neighborhoods (i.e., $40,279-51,534). Among 3-year-old children, 2014 obesity rates for the three lowest income neighborhoods were about 2.5 percentage points higher than in 2003. While 2014 obesity rates among 4-year-old children living in the second lowest income neighborhoods were 2.7 percentage points higher than in 2003, rates were back to 2003 levels among their counterparts living in the second highest income neighborhoods.

These differing patterns resulted in the absolute disparities in obesity by neighborhood median household income — the difference in obesity rates between the highest income neighborhood and the lowest income neighborhood— remaining relatively constant between 2003 and 2014 for 2- and 4-year-old children (2.2 and 1.7 percentage points, respectively) and increasing from 1.7 to 3.2 for 3-year-old children. However, absolute disparities were at their greatest in 2008 for 2- and 3-year-old children (nearly 4 percentage points for both) and in 2010 for 4-year-old children (3.5 percentage points).

These trends in obesity by neighborhood median household income varied by race/ethnicity (Figure 4.13). Among Hispanic children aged 2-5 years, obesity rates for the higher income neighborhoods increased until 2005, remained relatively stable until 2010, and then decreased. For Hispanic children in the lowest income neighborhoods, rates increased until 2008 and then decreased. Among NH blacks, obesity rates increased until 2008 and then decreased, although the trends varied by neighborhood income. Obesity rates among Asians increased slightly until 2005 and then decreased. Among NH whites, obesity rates among the different neighborhoods varied quite substantially but overall increased until 2005 and then started to decrease by 2008-11 at varying degrees.

The overall change in obesity rates between 2003 and 2014 varied by neighborhood median household income and race/ethnicity. The 2014 obesity rates among Hispanic children in all neighborhoods were 2.0-2.6 percentage points higher than in 2003, with the smallest increase among children in the highest income neighborhoods. Among Asian children, the 2014 obesity rates were 2.7 to 6.0 percentage points lower than the 2003 rates. Among NH black children, 2014 obesity rates were 1.9 percentage points higher than in 2003 for children living in the second lowest income neighborhoods. Among NH white children, the 2014 obesity rates were 2.2 percentage points lower than in 2003 among those children living in the second highest income neighborhoods.

Additionally, the absolute disparities in obesity by neighborhood median household income increased between 2003 and 2014 among Hispanics (1.5 to 2.0 percentage points), NH whites (2.8 to 3.2), and NH blacks (0.2 to 2.0), and decreased among Asians (1.9 to 1.3). In 2008, these disparities were wider among Hispanic (3.3 percentage points), NH white (5.0 percentage points) and NH black (2.3) children. Among Asian children, the disparities were -1.6 percentage points in 2008 but wider in 2010 at 2.9 percentage points.

Figure 4.10. Trends in obesity by neighborhood median household income among WIC-participating children aged 2 years: Los Angeles County, 2003-14

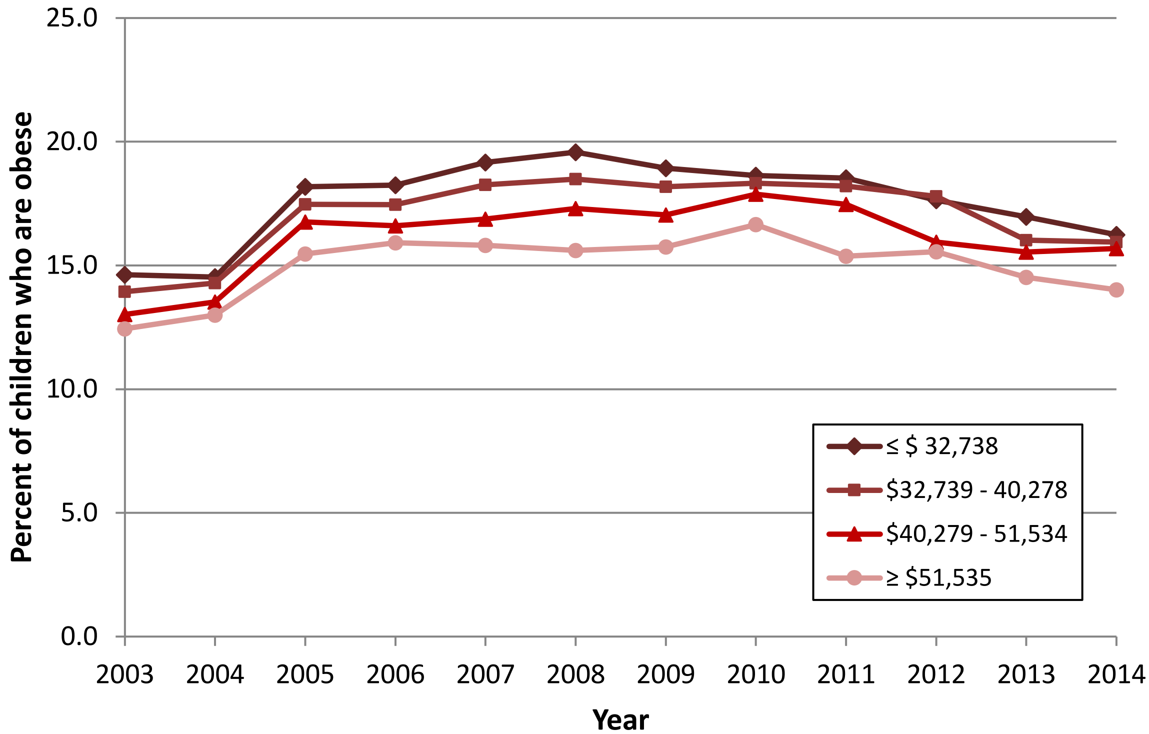


Figure 4.11. Trends in obesity by neighborhood median household income among WIC-participating children aged 3 years: Los Angeles County, 2003-14

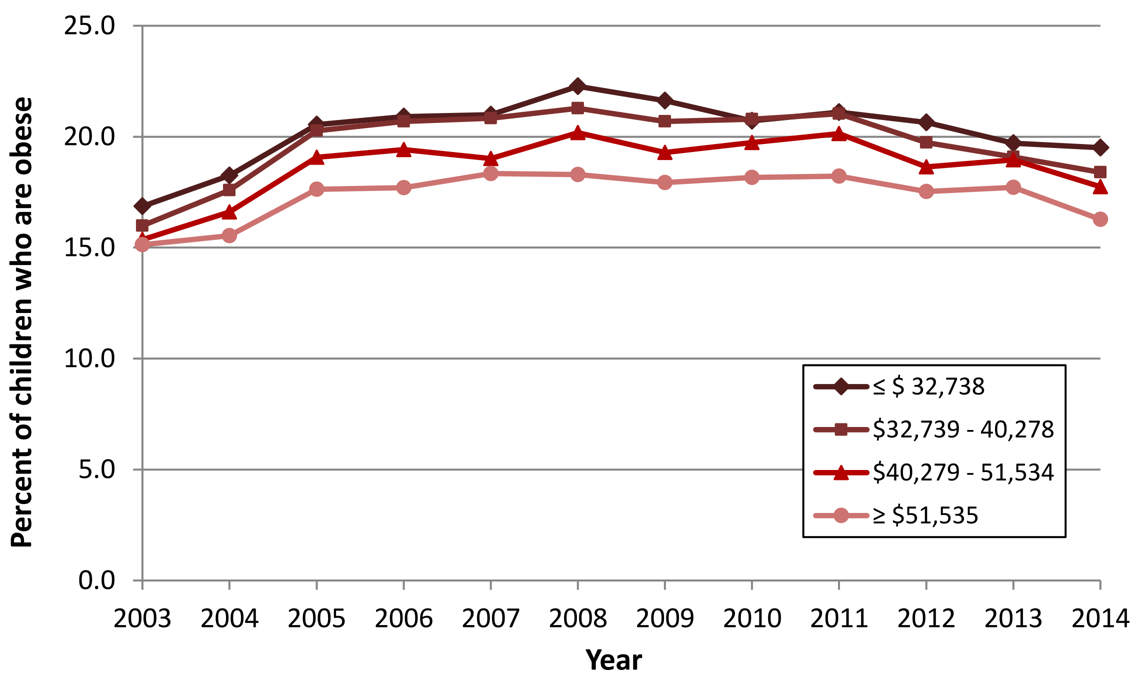


Figure 4.12. Trends in obesity by neighborhood median household income among WIC-participating children aged 4 years: Los Angeles County, 2003-14

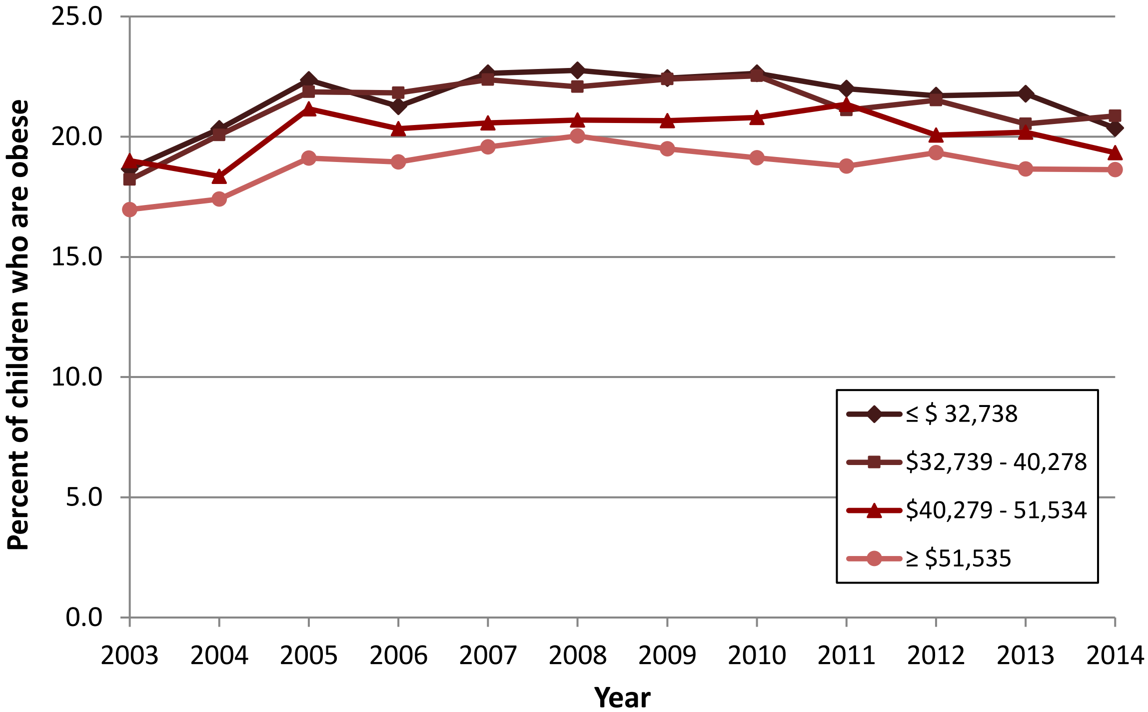
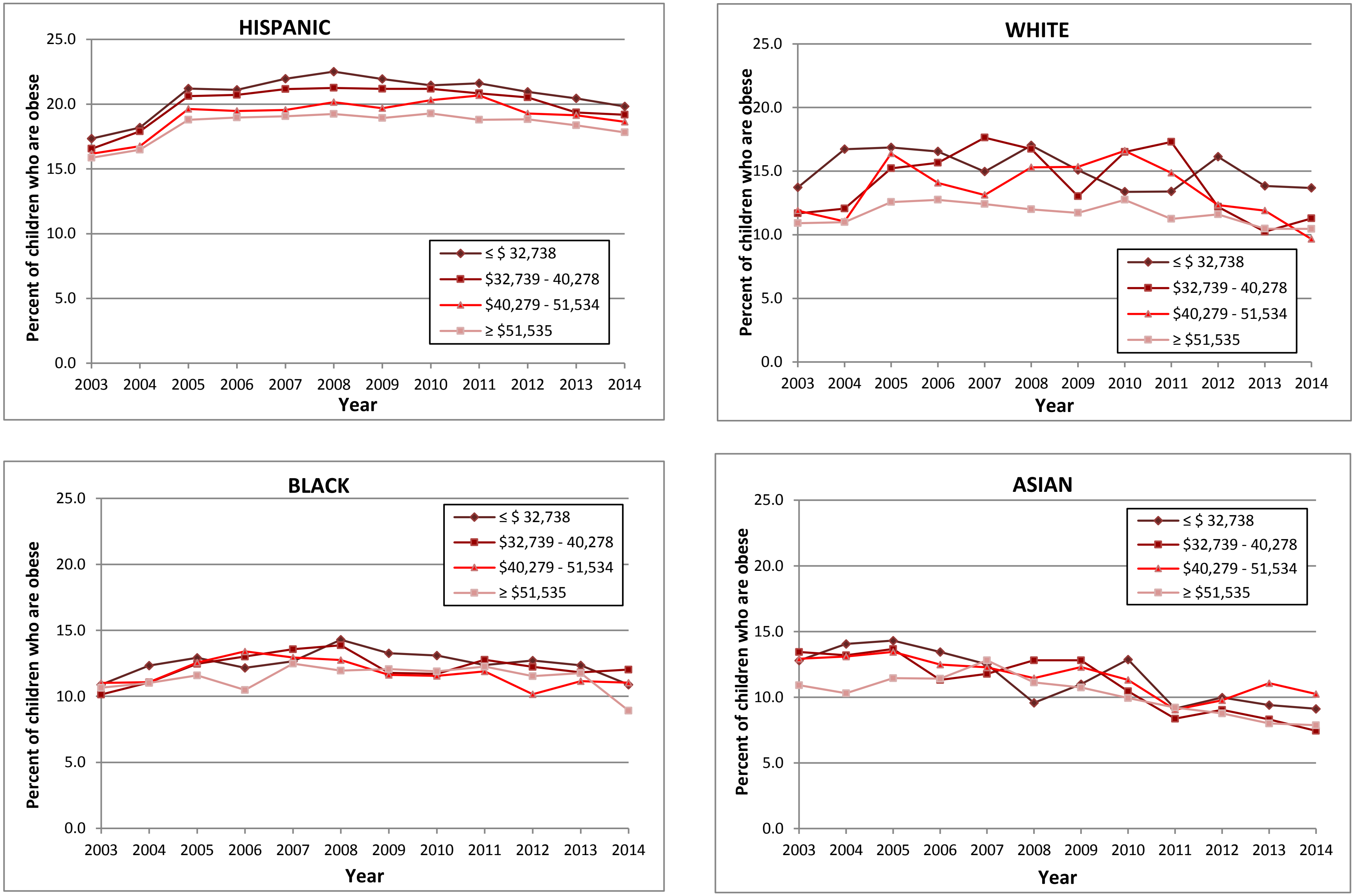


Figure 4.13. Trends in obesity by neighborhood median household income and race/ethnicity among children aged 2-5 years, 2003-14



Trends in obesity by neighborhood unaffordable housing

The trends in obesity by neighborhood unaffordable housing varied by child's age (Figures 4.14-16). Across all three age groups, obesity rates among children living in most neighborhoods increased until 2007-08. Obesity rates started to decrease around 2010-11 for 2-year old children (Figure 4.14), and 2009-10 for 3- and 4-year-old children (Figures 4.15 and 4.16). The rates of decrease tended to be similar for all four neighborhoods except for a sudden decrease in 2013 among 2-year-old children in the highest SES neighborhood, and a steeper decrease among 4-year-old children in the highest SES neighborhood, followed by a sudden increase in 2013.

Even though obesity rates decreased since 2009-11, 2014 obesity rates for all neighborhoods were still not back to 2003 rates. Among 2- and 3-year-old children in the lowest SES neighborhoods, 2014 obesity rates were about 3 percentage points higher than in 2003. The gain in obesity rates between 2003 and 2014 was smaller among the higher SES children. For example, among 4-year-old children, 2014 obesity rates were 2.2 and 3.7 percentage points higher than in 2003 for those living in the highest SES and lowest SES neighborhoods, respectively.

Absolute disparities in obesity by neighborhood unaffordable housing — the difference in obesity rates between the neighborhoods with the least unaffordable housing and the neighborhoods with the most unaffordable housing—were negligible for 3- and 4-year old children in 2003. However, the differing trends resulted in the absolute disparities increasing between 2003 and 2014 among all three age groups (2.4, 3.0, and 1.6 percentage points for 2-, 3- and 4-year-old children, respectively).

The trends in obesity by neighborhood unaffordable housing varied by race/ethnicity (Figure 4.17). Among Hispanic children aged 2-5 years, obesity rates for most neighborhoods increased until 2005, remained relatively stable until 2011, and then decreased. However, obesity rates among Hispanic children living in the lowest SES neighborhoods increased until

2007, and then decreased. Among NH black children, obesity rates increased until 2008 and then decreased with much variation during the time period. Obesity rates among NH white children living in the three highest SES neighborhoods increased until 2005, remained relatively stable and then decreased starting in 2010. Among their counterparts living in the lowest SES neighborhoods, obesity rates varied substantially during the 12-year period but started to decrease in 2011. Obesity rates among Asians in the three higher SES neighborhoods remained relatively stable until 2009 and then started to decrease. Obesity rates among Asians in the lowest SES neighborhoods increased until 2006, then decreased until 2012, and have since increased.

The 2014 obesity rates among Hispanic children were higher 2-3.5 percentage points higher than in 2003, with the greatest increase occurring among children in the lowest SES neighborhoods. Among NH white children, the 2014 obesity rates were 3 percentage points lower than in 2003 for those in the highest SES neighborhoods and 2.4 percentage points greater for those in the lowest SES neighborhoods. Among NH black children, the 2014 obesity rates were back to 2003 levels for the three highest SES neighborhoods, however, they were 2 percentage points higher for the lowest SES neighborhoods. Among Asian children, the 2014 obesity rates were 3 to 6.5 percentage points lower than 2003 levels, with the greatest decrease among children living in the lowest SES neighborhoods.

Additionally, the absolute disparities in obesity by neighborhood unaffordable housing increased between 2003 and 2014 among Hispanics (0.4 to 2.0 percentage points), NH whites (1.2 to 4.3), and NH blacks (0.5 to 3.4), and decreased among Asians (3.0 to -0.3).

Figure 4.14. Trends in obesity by neighborhood unaffordable housing among WIC-participating children aged 2 years: Los Angeles County, 2003-14

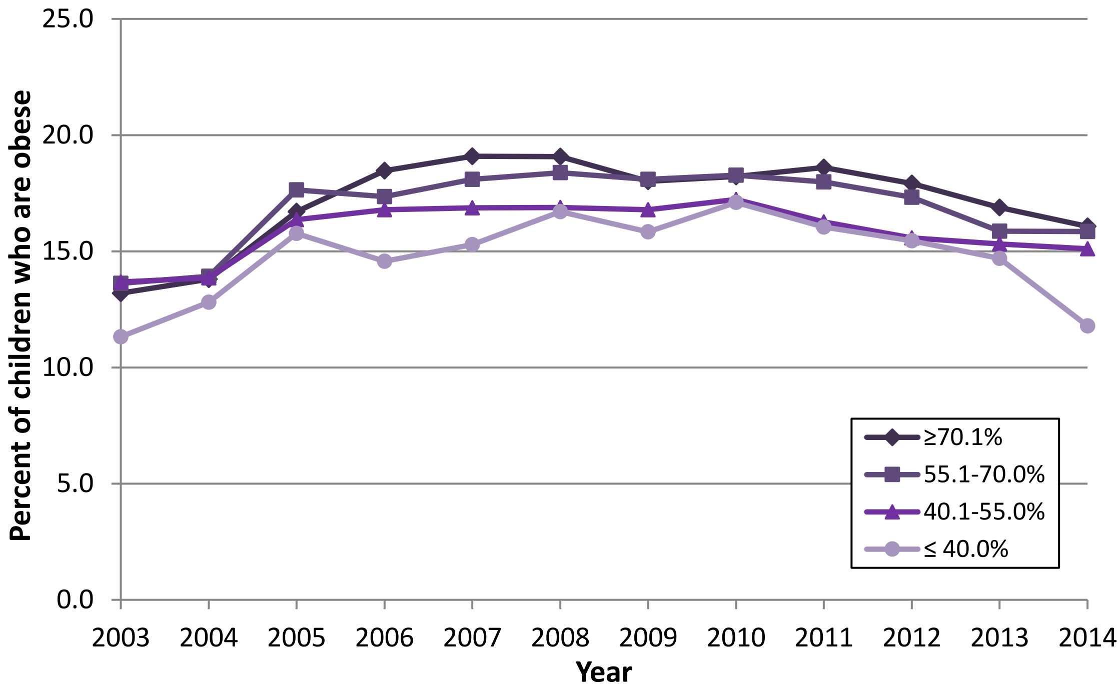


Figure 4.15. Trends in obesity by neighborhood unaffordable housing among WIC-participating children aged 3 years: Los Angeles County, 2003-14

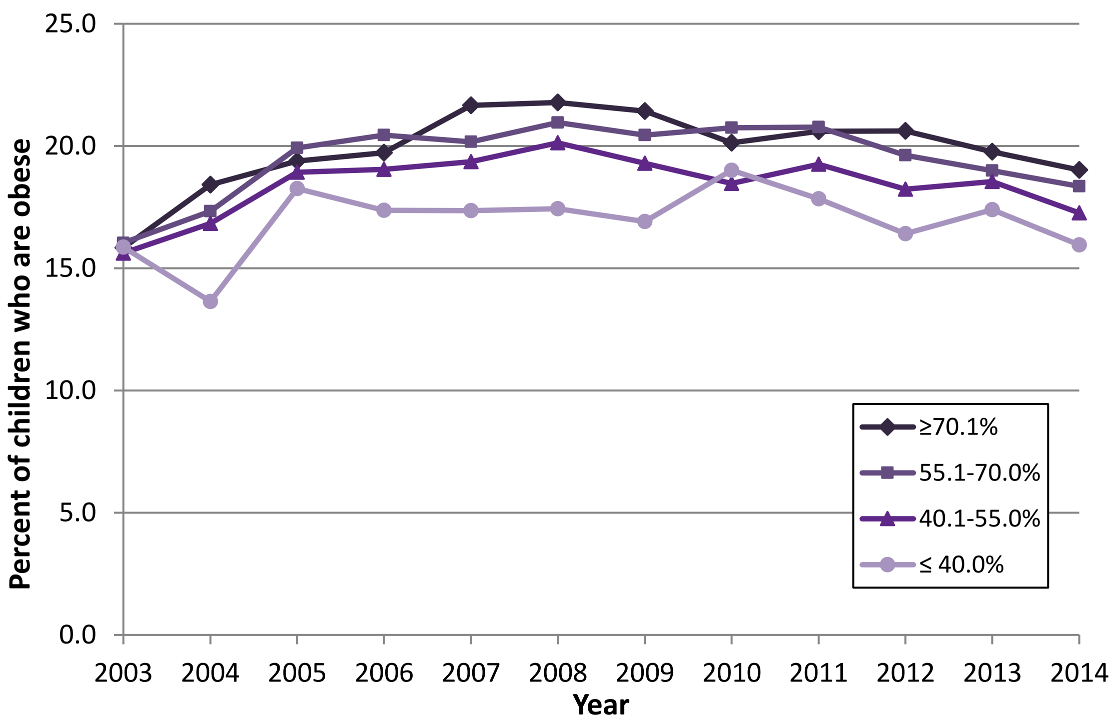


Figure 4.16. Trends in obesity by neighborhood unaffordable housing among WIC-participating children aged 4 years: Los Angeles County, 2003-14

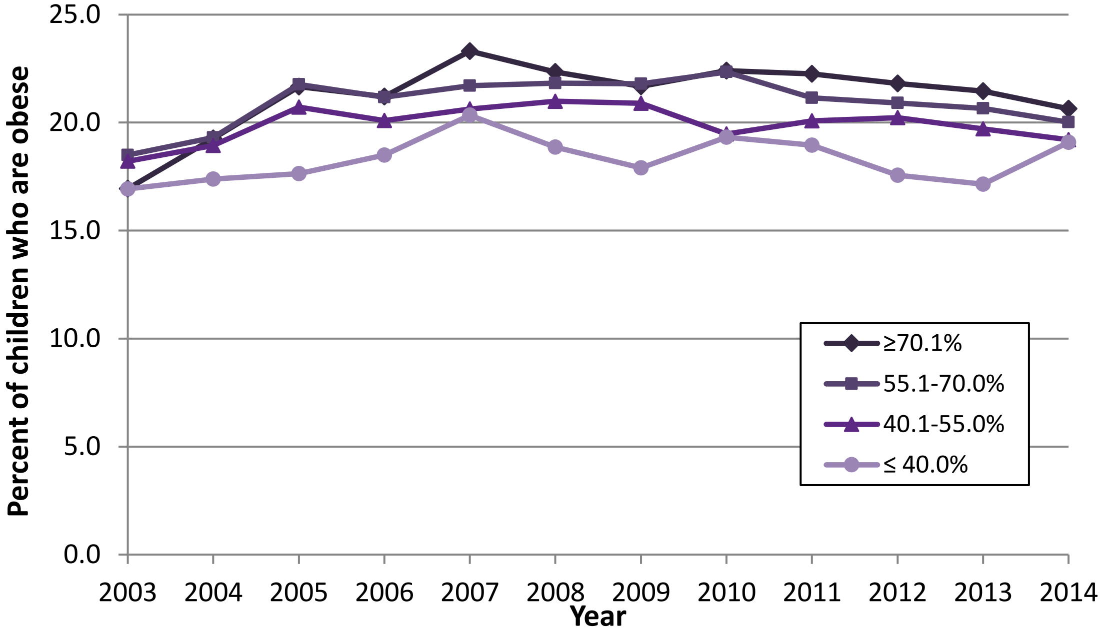
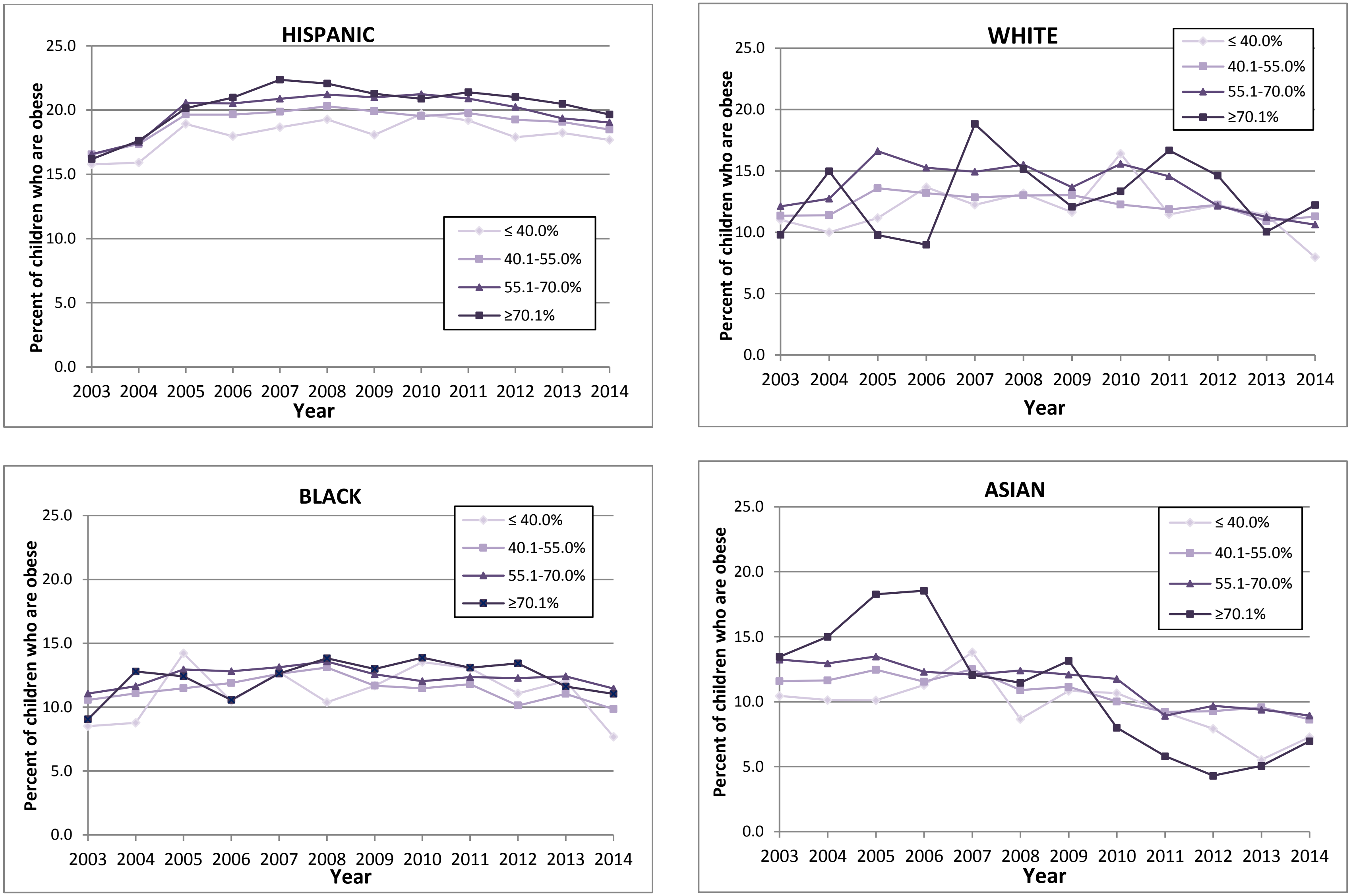


Figure 4.17. Trends in obesity by neighborhood unaffordable housing and race/ethnicity among children aged 2-5 years 2003-14



Discussion

In general, this study found that obesity rates among preschool-aged children participating in WIC in Los Angeles County increased until about 2008, remained relatively constant for a couple of years and then decreased beginning in 2010/11. The decreasing trend we found during the past few years is consistent with other studies that have examined trends in obesity rates among preschool-aged children (Ogden et al. 2014, Sekhobo et al. 2013). While obesity rates for preschool-aged children in the U.S. have decreased since 2003, among our low-income population 2014 obesity rates were, in general, not back to 2003 levels. However, differences in the trends in obesity rates existed by household- and neighborhood-level SES, child's age, and household race/ethnicity. Additionally, 2014 obesity rates among some higher SES children were back to 2003 levels, and even below them. A negative dose-response relationship with obesity was found by household- and neighborhood-level SES.

When examining the trends in obesity by household income, we found that 2014 obesity rates among 3- and 4-year-old children in the highest income households were back to 2003 levels. However, obesity rates increased among children living in lower-income households thereby widening the disparities in obesity between the highest and lowest income children over time. These differing trends could possibly be attributed to efforts to improve the food environment being more effective among higher-income children since their families have more financial resources to spend on healthy food.

A larger gradient in obesity by household income was observed among 2-year-old children than among 3- and 4-year-old children, suggesting that income might be more important among the younger children. While income disparities in obesity existed among WIC children, the difference in obesity rates between children in the highest SES families and lowest SES families was smaller than found for household education and for the neighborhood SES measures suggesting that income has a smaller effect on early childhood obesity among this population. The supplemental foods and nutrition education obtained from WIC may buffer the absolute deprivation experienced by these families. It is also possible that among WIC-participating children, other factors might be more important like household education and the neighborhoods in which they live.

Differences in obesity by household education existed in 2003, with a more pronounced dose-response relationship than was found for household income. In general, the pattern remained from 2003 to 2014. The reason that household education might be more important than household income could be, as discussed by Cohen et al. (2013) in their systematic review of educational attainment and adult obesity, that education might be more important among those with fewer resources (Cohen et al. 2013, Mirowsky and Ross 2003), or when prevention and treatment are known (Cutler and Lleras-Muney 2006). Education affects health through socioeconomic factors such as income and occupation (Adler and Newman 2002, Cohen et al. 2013). Since all of the children in our study are low income and the income gradient is not as pronounced as that of education, the education gradient in obesity could be due to households with higher education creating an "obesoprotective" environment for their children by engaging in healthier behaviors (Duncan et al. 2002).

Households with greater educational attainment may also be more likely to benefit from the interventions and policy, systems and environmental changes that have occurred in Los Angeles County (Cutler and Lleras-Muney 2006). Considerable resources have been invested in initiatives to address early childhood obesity in under-resourced communities in Los Angeles County (ChooseHealthLA! 2011, First 5 LA 2014). Many of these initiatives have attempted to address the lack of accessible healthy and fresh food as well as of recreational facilities for exercise in under-resourced communities (ChooseHealthLA! 2011, First 5 LA 2014).The decreasing obesity rates among 2- and 3-year-old children living in less educated households could mean that recent obesity prevention efforts are beginning to have an impact on mothers of all education levels.

Similar to other studies, we found that neighborhood socioeconomic conditions influence child's weight early on and that there is a negative relationship with obesity (Chaparro et al. 2014, Kimbro and Denney 2013, Nobari et al. 2013). Interestingly, we found that the disparities in obesity rates by neighborhood median household income were greatest for all three age groups around 2008-10. The disproportionate impact of the economic recession on the landscape in disadvantaged neighborhoods through the closing of food stores and foreclosures might be partially responsible for this by influencing diet and physical activity. The density of unhealthy food establishments started to decrease in Los Angeles County around 2007/08 whereas that of healthy food establishments started to increase at that time (Nobari et al. 2014). The 2009 WIC food package change also had a positive impact on increasing access to healthy foods in WIC-participants' neighborhoods (Andreyeva et al. 2012, Rose et al. 2014, Schultz, Byker Shanks and Houghtaling 2015, Zenk et al. 2014). As previously mentioned, during the last few years, multiple efforts and investments have been put into low-income communities in Los Angeles County to fight obesity as well as efforts by the Sheriff's Department to make parks safer in low-income neighborhoods (Ortega et al. 2015, Quinones 2015). These efforts could be partly responsible for the steeper decrease in obesity among the lowest SES children. Indeed, one study that examined trends in obesity rates among WIC-participating preschool-aged children in Los Angeles County from 2002 to 2011 hypothesized that the differing trends in obesity among adjacent census tracts could be due to different community-level efforts occurring in nearby neighborhoods (Chaparro, Wang and Whaley 2013). Given that 2014 obesity rates were still higher than in 2003 among those living in the higher SES neighborhoods, more community-level efforts are needed to overcome the deprivation and obesogenic-nature of these neighborhoods.

The use of neighborhood unaffordable housing to examine trends in early childhood obesity followed a similar pattern as with neighborhood median household income. This indicator may reflect the actual economic hardship and financial strain experienced by residents.

The increase in disparities in obesity by neighborhood unaffordable housing between 2003 and 2014 reflects the increasing impact of neighborhood financial strain on early childhood obesity.

When the socioeconomic trends in obesity were examined by household race/ethnicity, different patterns emerged. In general, Hispanic children aged 2-5 years experienced an increase in obesity rates and increasing disparities for all four SES measures. During the twelve-year time period, NH black and NH white children experienced relatively small overall changes in obesity rates and a widening of disparities. Asian children experienced a substantial overall decrease in obesity rates for all categories of the four SES measures, and a reduction in disparities for these SES measures. One possible reason for this overall decrease is that Asian households are more likely to live in Asian ethnic enclaves in Los Angeles and these neighborhoods may have greater socioeconomic resources, in addition to having fewer unhealthy stores (Nobari et al. 2013, Nobari et al. 2014).

We found a consistent negative dose-response relationship between obesity and each of the socioeconomic indicators over the 12-year-time period among Hispanic children. Depending on the SES indicator, the relationship between SES and obesity appeared to vary between 2003 and 2014 among NH black, NH white and Asian children. The variability in obesity rates by SES during the twelve-year period for NH black, NH white, and Asian children, could partly be attributed to the effect of SES on early childhood obesity changing during this twelve-year period. It might also be due to the relatively smaller sample size of NH black, NH white and Asian children.

During this study's twelve-year period, 2-year-old children experienced the greatest overall increase in obesity compared to 3- and 4-year-old children suggesting that greater efforts should be made to prevent obesity in the first two years of childhood. Research has often examined the association of disadvantage in early childhood with outcomes later in life (Lee et al. 2014); however, this study lends support that early disadvantage increases the risk of obesity in early childhood. We found socioeconomic disparities were pronounced in children as young as 2 years of age and Jones-Smith et al. (2014) found that trajectories of obesity risk by socioeconomic status begin to diverge as early as 9 months of age. Obesity prevention efforts should therefore include a focus on obesity risk factors during pregnancy and child's infancy such as mother's weight gain, exclusive breastfeeding, timing of complementary foods, and mother's chronic psychological stress.

This study had a number of strengths. We examined the trends in obesity by four different measures of SES with each reflecting a different dimension of SES. Most studies have examined trends by household income and none have examined trends by both a household- and a neighborhood-level SES measure. The different patterns observed by these different SES measures can help shed light on the etiology of childhood obesity. Additionally, our large sample size enabled us to have four categories for each SES measure and not three as is often the case in the literature (Braveman et al. 2010). Using more categories enabled us to determine that a dose-response relationship exists, especially after the late 2000's, which suggests a causal relationship between the SES indicator and childhood obesity (Braveman, Egerter and Williams 2011). We also examined trends in socioeconomic disparities stratified by race/ethnicity and found that socioeconomic disparities do exist among racial and ethnic minorities. Our findings lend support to the argument that socioeconomic disparities exist among racial/ethnic minorities and that they are not solely due to racial/ethnic disparities in obesity as posited by some researchers (Yongqing, Gordon and Sun 2014). Lastly, measured heights and weights of high validity were used (Crespi et al. 2012).

The study had a few limitations. First, our findings may not be generalizable to low-income children in other parts of the U.S. Second, there was great variability in the trends in obesity among the groups that had smaller sample sizes (see Appendix for tables of the samples sizes by SES, year, and child's age). For instance, among children whose caregivers had at least a college degree, the trends in obesity prevalence spiked or dipped, depending on age, around the time of the 2008-09 economic recession. It is possible that these changes were due to more college-educated individuals enrolling in WIC during that time period and thereby changing the trends in obesity. In 2009, the number of children with college-educated caregivers did increase by a few hundred for each of the three age groups (Appendix Table A.3). However, this represented only a few tenths of a percentage point. Instead, it could be that the relatively small sample size of approximately 1,500 to 2,100 children for this advantaged group lead to more unstable trends. While these are much smaller sample sizes than our total sample, childhood obesity trend studies using NHANES data oftentimes use unweighted sample sizes for children in the order of 350 to 700 children (Ogden et al. 2012).

Lastly, we discussed the absolute disparities in obesity, the change in the difference in obesity rates between the highest and lowest SES children, to describe the trends and illustrate how disparities changed over time. Future research should test whether disparities have statistically changed during this time period, adjusting for race/ethnicity, and should consider all four categories of the socioeconomic indicators as opposed to just the difference between the highest and lowest SES children.

Conclusion

In the fight against childhood obesity, the social and economic circumstances of families should be targeted. Efforts should be made to improve low-income mother's educational attainment and to continue to improve the physical and social environment of disadvantaged neighborhoods. Prevention efforts should also occur during the first two years of childhood as by age 2 socioeconomic differences in obesity are already evident. Among low-income populations, every effort should be made to target the more vulnerable members as our findings suggest that they are at increased risk of obesity and may not be reaping the greatest benefit from obesity-prevention interventions. Future research should explore the specific factors, programs and interventions that are responsible for the decreasing trend in early childhood obesity in Los Angeles County.

CHAPTER 5: Widening socioeconomic disparities in early childhood obesity in Los Angeles County, 2003-2014

Background

In the fight against the global epidemic of obesity, it has become clear that socioeconomic factors contribute significantly to differences in obesity prevalence (Cohen et al. 2013, Sobal and Stunkard 1989). In industrialized countries, obesity prevalence tends to be higher among those of lower socioeconomic status (SES), especially women (Cohen et al. 2013, Sobal and Stunkard 1989). Regardless of whether income or education is used as the indicator of SES, in the United States the prevalence of obesity is nearly 1.5 times higher among women of lower SES compared to women of higher SES (May et al. 2013, Ogden et al. 2010a). On the other hand, there is some evidence to suggest that obesity prevalence may be slightly higher among men of higher SES (May et al. 2013, Ogden et al. 2010a).

Among children, obesity prevalence is higher among children living in low SES households (Ogden et al. 2010b, Strauss and Knight 1999, Wang and Zhang 2006). Using 2005-08 NHANES data and household income as an indicator of household SES, Ogden et al. (2010b) reported that obesity prevalence was about 20% among 2-19 year-old girls and boys living in low-income families compared to about 12% among children living in higher-income families.

Since childhood obesity tracks into adulthood, with obese preschool-aged children more than four times as likely to become obese adults (Freedman et al. 2005, Guo et al. 2002, Juhola et al. 2011), increasing attention is being directed at investigating and understanding the socioeconomic disparities in obesity in this age group. Socioeconomic health disparities refer to differences in health that "adversely affect socially disadvantaged groups" (Braveman et al. 2011, Braveman 2014). Socioeconomic disparities in obesity risk suggest a need for the development and implementation of interventions that address the specific needs of the most socially and economically vulnerable groups, in order to ensure their ability to "attain the highest possible standard of health" (Braveman 2014).

Recent studies have found that socioeconomic disparities in childhood obesity may be widening (Babey et al. 2010, Frederick, Snellman and Putnam 2014, May et al. 2013, Ogden et al. 2010b, Singh, Siahpush and Kogan 2010b), although findings are inconsistent as they depend on the measures used and the time period studied (Rossen and Schoendorf 2012, Wang and Zhang 2006, Zhang and Wang 2007). To date, few studies have examined socioeconomic disparities with a focus on preschool-aged children. Despite national prevalence rates of early childhood obesity showing a decrease (Ogden et al. 2014), it is possible that socioeconomic disparities in early childhood obesity might be increasing.

In 2011, 15% of preschool-aged children living in low-income households were obese (Pan et al. 2015) compared to 8% for all preschool-aged children in the United States (Ogden et al. 2014). In Los Angeles County, 19% of preschool-aged children who participate in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) are obese (LA County WIC Data 2016). WIC serves more than half of all young children in Los Angeles County and provides nutritional support and education, breastfeeding support and referrals to medical and social services to low-income [≤185% federal poverty level (FPL)] and nutritionally at-risk pregnant, breastfeeding, and postpartum women, and infants and children less than five years old. Previously, in chapter 4 of this dissertation, we found that obesity prevalence among WIC children in Los Angeles County increased from 2003 until 2008 and then began to decrease in 2010-11. However, differing patterns in the trends in obesity by socioeconomic status may have resulted in a widening of the disparities between higher and lower SES children.

This widening in socioeconomic disparities among low-income children coincides with the 2008-09 economic recession. During the recession, low SES families experienced higher rates of unemployment and underemployment, resulting in higher losses in their income (Bohn and Schiff 2011, Joint Center for Housing Studies 2011, Ng, Slining and Popkin 2014).

California was one of the hardest hit states in the nation, experiencing some of the greatest increases in unemployment and income inequality (Bohn and Schiff 2011). Low income families in California experienced losses of 22% in their income while median-income families experienced losses of 11% (Bohn and Schiff 2011). Incomes have improved slightly since the recession but they are far from pre-recession levels, with low-income families experiencing the least improvement (Bohn and Danielson 2016). Child poverty rates in California are still higher than before the recession (23% in 2014 compared to 17% in 2007) (Bohn, Danielson and Bandy 2015).

Living in households that are poor or low-income, or that are headed by parents that have low educational attainment, increases the risk of obesity among children (CDC 2014, Ogden et al. 2010b). Children in these households are more likely to have unhealthy diets, be less physically active, experience more chaos and chronic stressors, and live in disadvantaged neighborhoods that are less likely to have access to healthy foods, safe recreational spaces, and social capital—all of which are risk factors for childhood obesity (Adler and Stewart 2010a, Braveman, Egerter and Barclay 2011, Lovasi et al. 2009, Schreier and Chen 2013). The economic recession might have also increased obesity risk among children living in low-income households since disadvantaged neighborhoods were disproportionately impacted through the closing of food stores and foreclosures (Tsai 2015), which may have influenced children's access to healthy foods, the safety of the neighborhoods, and parents' stress levels.

Using data gathered from WIC participants in Los Angeles County, this study seeks to determine whether household and neighborhood-level socioeconomic disparities in obesity rates among preschool-aged children have changed since 2003 by comparing the years prior to the 2008-09 economic recession to those following the recession.

This study tests the following hypotheses:

> Hypothesis 1: Disparities in early childhood obesity between higher and lower socioeconomic *households* are greater in the years following the 2008-09 economic recession compared to the years prior to the recession.

> Hypothesis 2: Disparities in early childhood obesity between higher and lower socioeconomic *neighborhoods* are greater in the years following the 2008-09 economic recession compared to the years prior to the recession.

Methods

WIC administrative data from 2003 to 2014 for Los Angeles County were used for this study. The data belong to the State of California WIC Program and are maintained by the WIC Data Mining Project, a research partnership which is funded by First 5 LA. Sociodemographic and anthropometric information on all participants since 2003 are included in the database. Height and weight measurements for children are obtained every six months by WIC staff who follow a standardized protocol for taking anthropometric measurements. These measurements have high validity (Crespi et al. 2012). Additional information on the data, the WIC Data Mining Project, and the protocol used for measurements can be found in chapter 4 of this dissertation.

WIC participants' addresses are geocoded at the census tract level. To obtain neighborhood socioeconomic information on the participants, we linked the Census Bureau's American Community Survey (ACS) data to participants' census tract of residence. Five-year estimates of ACS from 2005-09 were linked to measurements from 2003 to 2009 and 2010-14 five-year estimates of ACS were linked to measurements from 2010 to 2014.

The analyses were stratified by child's age (2, 3, and 4 years) since, due to their rapid growth, young children are developmentally and nutritionally different at every age (Tanner

1990). In preliminary analyses, logistic regressions were carried out to examine the association of childhood obesity and the interaction between socioeconomic variables and calendar year. Different transformations for year (as dummy variables, linear, quadratic, cubic, and binary) were used in the analyses. Based on Akaike information criterion (AIC) and predicted probability charts, the binary year variable (2003-07 vs 2010-14) provided one of the best fits for the data since it allowed for flexibility to model the increasing trends up until 2008 and the decreasing trends beginning in 2010.

Observations were included if they represented a child's first weight/height measurement in a calendar year and if the measurement occurred in the years 2003-07 or 2010-14. Children with missing data on any of the relevant variables were excluded. The total sample size was 1,658,101, with 605,326 children aged 2 years, 584,349 aged 3 years, and 468,426 children aged 4 years. Since children can participate in WIC up until their 5th birthday, the same child could be included in the different samples.

Variables

Body mass index [BMI = weight (kg)/height (m) ^{2}] was calculated from measured weight and height for each child. *Obesity status* was determined by a BMI ≥ 95th percentile of CDC's gender- and age-specific growth reference values (Kuczmarski et al. 2002).

Four different aspects of SES were examined, two at the household level and two at the neighborhood level. Each measure reflects a different facet of the child's standard of living and environment. *Household income* includes income from all sources such as wages, unemployment compensation, social security benefits, State Disability Insurance, public assistance, and child support and was operationalized as a percentage of the Federal Poverty Level (FPL) [≤50% FPL, 51-100% FPL%, 101-135% FPL, and 136-185% FPL]. *Household education* indicates the highest grade completed by the child's caregiver at the time of enrollment, and was categorized as less than high school, high school, some college, college or more. *Neighborhood median household income* is the 5-year estimate of the median household income of residents living in the child's census tract and was categorized according to the quartiles of the distribution among WIC participants (≤$ 32,738; $32,739-40,278; $40,279-51,534; ≥51,535); as a reference, the highest neighborhood income group has a lower median income than that of all of Los Angeles County ($55,870 in 2014 dollars) (U.S. Census Bureau 2016). *Neighborhood unaffordable housing*, an indicator of residents' economic hardship, is the 5-year estimate of the percentage of residents living in the child's census tract that live in unaffordable housing (i.e., spending > 30% of income on housing-related costs), and was categorized as ≤ 40%, 40.1-55.0%, 55.1-70.0%, and ≥ 70.1%. For these four socioeconomic variables, dummy variables were used in the analyses with the highest SES group considered the reference.

A binary 5-year period variable (2003-07 vs. 2010-14) based on the calendar year the child was weighed and measured was used. The analyses were stratified by age and age was calculated as the difference between the child's date of birth and the date of measurement. The analyses were adjusted for child's gender and caregiver race/ethnicity since these are associated with obesity (Kit, Ogden and Flegal 2014, Linabery et al. 2013, Wang and Zhang 2006). Caregiver race/ethnicity was categorized as Hispanic, Non-Hispanic (NH) white, NH black and Asian and three dummy variables were created with Hispanic as the reference group since the majority of the children were from Hispanic households.

Statistical Analysis

Chi-square tests were used to examine whether participants' sociodemographic characteristics were different during the two time periods. To determine whether socioeconomic disparities in obesity have changed since the recession, we examined whether the effect of SES on obesity was different for the two time periods (2003-07 vs 2010-14). For each SES variable, logistic regression analyses were conducted to examine the association of childhood obesity and the interaction term of SES with the 5-year period variable, stratified by child's age and adjusted for child's gender and caregiver's race/ethnicity. Logistic regression analyses were conducted for all of the SES variables: household income, household education, neighborhood median household income and neighborhood unaffordable housing. The following is the equation of the multivariate logistic regression which was used for each of the 4 independent SES variables:

$$\text{logit}[P(Y=1)] = \beta_0 + \beta_1 (\text{SES}_i) + \beta_2 (\text{Gender}_i) + \beta_3 (\text{Race/ethnicity}_i) + \beta_4 (\text{5-year period}) + \beta_5 (\text{5-year period*SES}) + e_i$$

Y is the log odds that child i is obese
β_{0i} is the common intercept across the sample of children
β_1 is the effect of SES on obesity holding covariates constant
SES refers to the household (or neighborhood) SES of child i
β_2 is the effect of gender on obesity holding covariates constant
Gender refers to the gender of child i
β_3 is the effect of race/ethnicity on obesity holding covariates constant
Race/ethnicity refers to the race/ethnicity of child i's caregiver
β_4 is the effect of the 5-year period on obesity for child i holding covariates constant
5-year period refers to the period of time of child i's measurement
β_5 is the effect of the interaction term of 5-year period and SES on obesity holding covariates constant
5-year period* SES_i refers to the interaction term of SES and 5-year period for child i
e_i is the random error for child i with distribution N $(0, \sigma_u^2)$

To determine if disparities changed in the years following the economic recession (2010-14) compared to the years prior to the recession (2003-07), the statistical significance of the interaction between the categorical SES variable and the binary 5-year period variable was examined using the omnibus Wald chi-square test statistic. Since this test-statistic only tests for overall statistical difference, the individual t-statistics were used to determine which parameters were statistically different from the reference (the high SES group in 2003-07). Tests for statistical significance were based on a p-value < 0.05. Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

Results

During both time periods (2003-07 and 2010-14), the sample had approximately equal percentages of girls and boys (see Table 5.1). Obesity prevalence was higher among the older children (4-year olds). Between 2003-07 and 2010-14, obesity prevalence increased slightly for 2- and 3-year old children but remained relatively constant for 4-year old children (Table 5.1).

The sociodemographic make-up of the WIC population in Los Angeles County changed between 2003-07 and 2010-14 (Table 5.1). The majority of children had caregivers who were Hispanic and this percentage increased between 2003-07 and 2010-14. Consequently, the proportion of children with NH white or Asian caregivers decreased between 2003-07 and 2010-14. The proportion of children with caregivers with at least a high-school education increased between 2003-07 and 2010-14. Among 2-year-old children, the percentage increased from 41% to 51%. In 2010-14, children were more likely to live in extreme poverty (≤ 50% FPL) and in neighborhoods where more than 70% of residents live in unaffordable housing than they had in 2003-07 (Table 5.1).

Table 5.1. Sociodemographic characteristics of WIC children in Los Angeles County by age and 5-year time period, 2003-2014

	2 year-olds N=605,326 %		**3 year-olds** N=584,349 %		**4 year-old** N=468,426 %	
	2003-07 N=324,102	2010-14 N=281,224	2003-07 N=309,215	2010-14 N=275,134	2003-07 N=246,781	2010-14 N=221,645
Child's gender (female)	49.0	49.0	48.9	49.0	48.9	48.9
% children who are obese	15.7	16.6***	18.3	19.1***	20.1	20.5***
Caregiver race/ethnicity						
NH white	4.4	3.4***	4.2	3.1***	4.3	3.0***
NH black	7.3	7.6	7.1	7.1	7.0	6.4
Asian	4.3	3.8	4.2	3.6	4.0	3.5
Hispanic	84.0	85.2	84.5	86.2	84.7	87.1
Household income						
≤ 50% FPL	22.6	31.9***	22.7	30.9***	22.6	30.1***
50.1 – 100.0% FPL	45.7	44.6	45.8	45.9	46.1	47.1
100.1 – 133.0% FPL	17.9	13.6	17.8	13.6	17.8	13.4
133.1 – 185.0% FPL	13.8	9.8	13.7	9.7	13.5	9.4
Household education						
< High school	59.1	48.9***	60.4	50.5***	61.5	52.4***
High school	30.1	36.3	29.3	35.5	28.6	34.4
Some college	8.3	10.8	8.0	10.2	7.7	9.6
College or more	2.6	4.1	2.3	3.8	2.2	3.6
Neighborhood Median Household Income						
≤ $ 32,738	24.7	25.6***	24.9	25.8***	24.8	25.9***
$32,739 - 40,278	26.0	23.2	26.2	23.5	26.2	23.7
$40,279 - 51,534	25.3	24.4	25.3	24.4	25.5	24.6
≥ $51,535	23.9	26.9	23.6	26.3	23.4	25.9
Neighborhood Unaffordable Housing†						
≥70.1%	5.1	10.6***	5.2	10.7***	5.1	10.6***
55.1-70.0%	49.6	50.4	49.6	50.8	49.8	51.3
40.1-55.0%	41.2	34.5	41.2	34.1	41.1	33.9
≤ 40.0%	4.1	4.5	4.0	4.4	4.0	4.3

Obesity is having a BMI ≥ 95^{th} percentile of CDC's gender- and age-specific growth reference values
FPL = Federal poverty level.
Chi-square test measuring differences by time period * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
†Percent of residents living in unaffordable housing (i.e., spending > 30% of income on housing costs).

Early childhood obesity by household- and neighborhood-level SES

In general, a negative dose-response relationship existed with early childhood obesity and each of the four socioeconomic indicators (Table 5.2), with higher prevalence of obesity among children living in the lowest SES households or neighborhoods and lower prevalence among children living in the highest SES households or neighborhoods. However, the gradient was not clear-cut for every indicator, age and time period. For instance, obesity prevalence among 3-year-old children in the lowest two household income groups was the same (18.5% in 2003-07 and 19.5% in 2010-14) (Table 5.2).

For the household SES indicators, the absolute disparities—the difference in obesity prevalence between the lowest and highest SES group—increased by approximately 1 percentage point between the two time periods for all three age groups. For household income, the absolute disparities increased from 1.8 to 2.4 percentage points for 2-year old children in 2003-2007 vs. 2010-2014, and 1.0 to 2.2 and 0.7 to 1.7 for 3 and 4-year old children, respectively [calculations not shown in Table 5.2]. For household education, the absolute disparities increased from 5.4 to 6.3 percentage points for 2-year old children in 2003-2007 vs. 2010-2014, and 5.3 to 6.0 and 4.9 to 5.9 for 3 and 4-year old children, respectively. For the neighborhood SES indicators, the absolute disparities remained relatively unchanged except for neighborhood unaffordable housing among 4-year old children where the absolute disparities increased by 1 percentage point.

Table 5.2. Prevalence of obesity among WIC children in Los Angeles County by age and socioeconomic indicators, 2003-2014

	2 year-olds N=605,326 %		3 year-olds N=584,349 %		4 year-olds N=468,426 %	
	2003-07 N=324,102	2010-14 N=281,224	2003-07 N=309,215	2010-14 N=275,134	2003-07 N=246,781	2010-14 N=221,645
Household income						
≤ 50% FPL	16.6***	17.4***	18.5***	19.5***	20.1**	20.6***
50.1 – 100.0% FPL	15.7	16.5	18.5	19.5	20.2	21.1
100.1 – 133.0% FPL	15.4	15.9	18.2	18.3	20.1	19.4
133.1 – 185.0% FPL	14.8	15.0	17.5	17.3	19.4	18.9
Household education						
< High school	16.5***	17.7***	19.2***	20.3***	21.0***	21.6***
High school	15.2	16.3	17.3	18.6	19.0	19.9
Some college	13.7	14.6	16.5	17.1	17.7	18.7
College or more	11.1	11.4	13.9	14.3	16.1	15.7
Neighborhood Median Household Income						
≤ $ 32,738	16.9***	17.6***	19.4***	20.3***	21.0***	21.7***
$32,739 - 40,278	16.2	17.2	19.0	19.8	20.8	21.3
$40,279 - 51,534	15.3	16.4	17.8	19.0	19.9	20.3
≥ $51,535	14.5	15.2	16.8	17.5	18.4	18.9
Neighborhood Unaffordable Housing†						
≥70.1%	16.2***	17.5***	19.0***	20.0***	20.4***	21.7***
55.1-70.0%	16.1	17.0	18.7	19.7	20.5	21.0
40.1-55.0%	15.5	15.9	17.9	18.3	19.7	19.8
≤ 40.0%	13.9	14.9	16.5	17.3	18.1	18.4

Obesity is having a BMI ≥ 95^{th} percentile of CDC's gender- and age-specific growth reference values
FPL = Federal poverty level.
Chi-square test measuring differences within time periods * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
†Percent of residents living in unaffordable housing (i.e., spending > 30% of income on housing costs).

Multivariate analyses

Since results from the multiple logistic regression analysis examining whether the effect of SES on obesity was different for the two time periods were similar by household and neighborhood-level SES, the results for one household-level SES indicator (household income) and one neighborhood-level SES indicator (neighborhood median household income) are shown in Tables 5.3 and 5.4. The results for the other two indicators are shown in the Appendix (Tables B1 and B2). The results for household income among 2- and 3-year-old children are discussed in detail and a summary of the main findings for all four indicators is in Table 5.5.

Among 2-year-old children, compared to children living in the highest income households (133.1-185.0% FPL) and after adjusting for child's gender, caregiver's race/ethnicity and the 5-year time period: 1) living in a household with income ≤ 50% FPL was associated with a statistically significant increase of 0.166 (0.013) in the log odds of obesity; 2) living in a household with income 50.1-100.0 % FPL was associated with a statistically significant increase of 0.061 (0.012) in the log odds of obesity; and 3) living in a household with income 100.1-133.0% FPL was associated with a statistically significant increase of 0.037 (0.014) in the log odds of obesity.

Among 2-year-old children, the log odds of obesity in 2010-14 compared to 2003-07, increased by 0.044 (0.007), after adjusting for child's gender, caregiver's race/ethnicity, and household income (Model 1 for 2-year-old children in Table 5.3).

To determine if the effect of household income on childhood obesity was significantly different between both time periods, an interaction term between the household income and the 5-year period variable was examined (Model 2 in Table 5.3). Among 2-year-old children, the Wald chi-square test statistic of the interaction term was not significant at $p < 0.05$ (Model 2 for 2-year-old children in Table 5.3). Therefore, the effect of household income on childhood obesity did not change between the two time periods and the disparities in obesity by household income did not change during this time.

Among 3-year-old children, the Wald chi-square test statistic of the interaction term of household income and the 5-year time period was statistically significant (Model 2 for 3-year-old children in Table 5.3). Since the coefficients for each of the categories in the interaction term were positive when compared to the reference group, the effect of SES on obesity increased between 2003-07 and 2010-14. Among 3-year-old children, the log odds of the effect on obesity of living in a household with income ≤ 50% FPL compared to living in the highest income households (133.1-185.0% FPL) increased by 0.049 between 2003-07 and 2010-14 (Model 2 for 3-year-old children in Table 5.3). This translates into the odds ratio (OR) of being obese for children in households with income ≤ 50% FPL compared to children living in the highest income households increasing from 1.11 in 2003-07 to 1.16 2010-14, holding all other covariates constant [calculations not shown].

The log odds of the effect on obesity of living in a household with income 50.1-100.0 % FPL compared to living in the highest income households (133.1-185.0% FPL) increased by 0.067 between 2003-07 and 2010-14 (Model 2 for 3-year-old children in Table 5.3). Therefore, the odds ratio (OR) of being obese for children in households with income 50.1-100.0 % FPL compared to children living in the highest income households increased from 1.05 in 2003-07 to 1.12 in 2010-14, holding all other covariates constant [calculations not shown]. The log odds of the effect of living in a household with income 100.1-133.0% FPL did not significantly change between 2003-07 and 2010-14.

For 4-year old children, the interaction between household income and the 5-year period variable was statistically significant after adjusting for child’s gender and caregiver race/ethnicity (Table 5.3). For 2- and 3-year old children, the interaction term between household education and the 5-year period variable was statistically significant after adjusting for child’s gender and caregiver race/ethnicity (Table B1 in Appendix). The interaction terms between the 5-year period and neighborhood household median income were not statistically significant for the three age groups (Model 2 in Table 5.4) nor were they significant when neighborhood unaffordable housing was examined (Table B2 in Appendix).

In summary, controlling for child's gender and caregiver race/ethnicity, the effect of household income and household education on early childhood obesity significantly increased from the time before the recession to after the recession among some of the children, thereby widening the disparities (Table 5.5). The effect of neighborhood median household income and unaffordable housing on childhood obesity did not significantly change between the two time periods among children of all three age groups. Hence, the disparities in childhood obesity by these neighborhood-level SES indicators did not significantly change from the time before the recession to after the recession (Table 5.5).

Household-level SES: household income

Table 5.3. Multiple logistic regression analyses for obesity and household income for WIC children in Los Angeles County† across all three age groups

	2-year-old children N=605,326		**3-year-old children** N=584,349		**4-year-old children** N=468,426	
	Model 1 b(SE)	Model 2 b(SE)	Model 1 b (SE)	Model 2 b (SE)	Model 1 b(SE)	Model 2 b(SE)
Income (133.1-185.0% FPL, Ref)						
≤ 50% FPL	0.166 (0.013)*** [c]	0.162(0.017)*** [c]	0.121 (0.012) ***[c]	0.102(0.016)*** [c]	0.083 (0.013) *** [c]	).072(0.018)*** [c]
50.1-100.0 % FPL	0.061 (0.012)***	0.052(0.015)***	0.073 (0.011) ***	0.045 (0.015) **	0.062 (0.012)***	0.033 (0.016)*
100.1-133.0% FPL	0.037 (0.014) **	0.033 (0.018)	0.036 (0.013) **	0.027 (0.017)	0.021 (0.014)	0.024 (0.018)
2010-14 time period (2003-07, Ref)	0.044 (0.007) ***	0.029 (0.022)	0.039 (0.007) ***	-0.010 (0.021)	0.012 (0.007)	-0.030 (0.023)
Income x 2010-14 time period (133.1-185.0% FPL in 2003-07, Ref)						
≤ 50% FPL, 2010-14		0.012 (0.025)		0.049 (0.025)* [a]		0.032 (0.027) [c]
50.1-100.0 % FPL, 2010-14		0.0222 (0.024)		0.067 (0.023)**		0.071 (0.025)**
100.1-133.0% FPL, 2010-14		0.011 (0.028)		0.025 (0.027)		-0.006 (0.030)

†All models adjusted for child's gender and caregiver's race/ethnicity
FPL = Federal poverty level; Ref=reference group.
t-statistic significant at * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Wald chi-square significant at [a] $p < 0.05$; [b] $p< 0.01$; [c] < 0.001

Neighborhood-level SES: neighborhood median household income

Table 5.4. Multiple logistic regression analyses for obesity and neighborhood median household income for WIC children in Los Angeles County† across all three age groups

	2-year-old children N=605,326		**3-year-old children** N=584,349		**4-year-old children** N=468,426	
	Model 1 b(SE)	Model 2 b(SE)	Model 1 b (SE)	Model 2 b (SE)	Model 1 b(SE)	Model 2 b(SE)
Median household income (≥ $51,535, Ref)						
≤ $ 32,738	0.144 (0.010)*** c	0.138 (0.014)*** c	0.148 (0.010)*** c	0.138 (0.014)*** c	0.134 (0.011)*** c	0.125 (0.015)*** c
$32,739 - 40,278	0.096 (0.010)***	0.083 (0.014) ***	0.105 (0.010)***	0.100 (0.013)***	0.108 (0.011)***	0.107(0.015)***
$40,279 - 51,534	0.045 (0.010)***	0.022 (0.014)	0.051 (0.010)***	0.031 (0.014)*	0.061 (0.011)***	0.057 (0.015)***
2010-14 time period (2003-07, Ref)	0.060 (0.007)***	0.038 (0.014)**	0.050 (0.007)***	0.032 (0.014)*	0.020 (0.007)**	0.013 (0.015)
Median household income x 2010-14 time period (≥ $51,535 in 2003-07, Ref)						
≤ $ 32,738, 2010-14		0.011 (0.020)		0.020 (0.019)		0.018 (0.021)
$32,739 - 40,278, 2010-14		0.027 (0.020)		0.007 (0.019)		0.002 (0.021)
$40,279 - 51,534, 2010-14		0.047 (0.020) *		0.042 (0.020) *		0.007 (0.021)

†All models adjusted for child's gender and caregiver's race/ethnicity
FPL = Federal poverty level; Ref=reference group.
t-statistic significant at * p < 0.05; ** p < 0.01; *** p < 0.001
Wald chi-square significant at [a] p < 0.05; [b] p< 0.01; [c] < 0.001

Table 5.5. Summary of findings of change in disparities in childhood obesity by each socioeconomic indicator between 2003-07 and 2010-14, and by child's age

	2-year-old children	3-year-old children	4-year-old children
Household-level SES			
Household income	—	↑	↑
Household education	↑	↑	—
Neighborhood-level SES			
Median household income	—	—	—
Neighborhood unaffordable housing	—	—	—

↑Positive significant association of the interaction of the SES indicator with 2010-14 time period, representing a widening of disparities between 2003-07 and 2010-14;
— No significant association (no change in disparities); and
↓ Negative significant association (narrowing of disparities)

Discussion

Among preschool-aged children participating in WIC, we found that household-level socioeconomic disparities in obesity exist and that these disparities widened in the years following the 2008-09 economic recession compared to the years prior to the recession. While neighborhood-level socioeconomic disparities in early childhood obesity also exist, we did not find the disparities to have changed during this time period.

Our findings are consistent with studies among older children that found an increase in household-level socioeconomic disparities in obesity (Babey et al. 2010, Frederick, Snellman and Putnam 2014, May et al. 2013, Singh, Siahpush and Kogan 2010b). However, two recent studies found that disparities in childhood obesity by household income have not changed. Despite using multiple disparity indices, Rossen and Schoendorf (2012) did not find that income disparities in obesity among children aged 2-18 years changed from 2001 to 2010. Another recent study examined the overall effect of household income on obesity among preschool-aged children and found that while the overall effect of household income on obesity did not change between 2003-04 and 2011-12, it did weaken among boys (Kranjac and Wagmiller 2016). The difference in findings between our study and these two could be due to the different study samples. Both of these studies examined a nationally representative sample using NHANES data while our sample was of children living in low-income households. Household income may have a greater effect on obesity risk among low-income families where financial resources are lacking. Rossen and Schoendorf (2012) also examined disparities among all children (2-18 year olds) and not solely preschool-aged children. Furthermore, neither study examined disparities up to 2014. It could be that the widening in socioeconomic disparities becomes more evident as income inequality increases (Bohn and Danielson 2016). More time has occurred since the economic recession and low SES families' financial situation has still not returned to the levels seen prior to the recession (Bohn and Danielson 2016). Lastly, the difference in findings could be because our study occurred in California and the state was one of the most affected by the recession (Bohn and Schiff 2011).

The factors contributing to the widening socioeconomic disparities in obesity at the household level are not clear and merit further exploration. Factors such as having a high energy intake or being sedentary may be contributing to increasing socioeconomic disparities in obesity. Increasing secular trends have been found in energy intake among preschool-aged children in low-education and low-income households since the 1970s while a decreasing trend has been found among children in college-educated households (Kant and Graubard 2013). Although they examined adolescents, Frederick et al. (2014) found that while most children decreased their energy intake between 1999 and 2010, children in college-educated families experienced the greatest decrease compared to children in families with no more than a high school degree. The authors also found increasing socioeconomic disparities in physical activity during this time period, with children in college-educated families becoming more physically active and those in less educated households becoming less physically active (Frederick, Snellman and Putnam 2014).

Another reason for the widening disparities by household income and education could be that population-based interventions and efforts are more likely to benefit higher SES individuals (Rossen and Schoendorf 2012). Higher SES individuals have greater financial resources to take advantage of interventions. For instance, higher income families may be more likely to benefit from their food environment improving since they have greater financial resources to spend on food. Since we found that income disparities in obesity increased only for the 3- and 4-year-old children, it is possible that financial resources are more important for older children.

Education improves reading skills, the ability to critically think and make decisions, and the likelihood to focus on long-term outcomes (Cutler and Lleras-Muney 2006). These skills may allow higher-educated parents to take greater advantage of various types of obesity-prevention efforts. Higher educated parents may also experience more control and less chronic psychosocial stress during negative life events like the economic recession (Cutler and Lleras-Muney 2006) thereby maintaining nurturing, stable environments for their children. Chronically stressed parents and chaotic home environments can increase a child's stress levels and subsequently increase the child's risk of obesity (Garasky et al. 2009, Gundersen et al. 2011, Gunnar and Quevedo 2007, Lumeng et al. 2014). Given that education disparities in obesity increased only for the 2- and 3-year old children, it could be that younger children reap greater benefits from having more educated parents than older children.

The lack of change we found in the disparities in obesity by neighborhood socioeconomic indicators may be partly due to the community-based obesity-prevention initiatives that began to occur in Los Angeles since 2009. To combat the high early childhood obesity rates in under-resourced communities in Los Angeles County, First 5 LA, the Los Angeles County Department of Public Health and other organizations invested in Reducing Early Childhood Obesity initiatives such as the Early Childhood Obesity Prevention Initiative (ChooseHealthLA! 2011, First 5 LA n,d.). Many of these initiatives attempted to influence the proximal risk factors of early childhood obesity, mainly diet, physical activity, and breastfeeding, by addressing community-based public education, the lack of healthy and fresh food as well as recreational facilities for exercise (ChooseHealthLA! 2011, First 5 LA n,d.). These initiatives may have alleviated the negative repercussions of the recession on neighborhoods. Indeed, our previous work examining trends in early childhood obesity by neighborhood socioeconomic indicators suggests that the greatest differences in obesity occurred in 2008-2010 (chapter 4 of this dissertation).

Additionally, a major legislative change occurred in 2009 affecting the foods offered by the WIC program to participating families (72 C.F.R. § 68966). The change subsequently increased the availability of healthier foods in WIC-participating families' homes and neighborhoods (Andreyeva et al. 2012, Andreyeva et al. 2014, Chiasson et al. 2013, Odoms-Young et al. 2014, Rose et al. 2014, Schultz, Byker Shanks and Houghtaling 2015, Whaley et al. 2012, Zenk et al. 2014). While some food establishments closed during the economic recession, the food environment might have improved slightly since the density of unhealthy food establishments declined and that of healthy food establishments increased in Los Angeles County during the recession (Hsu 2012, Nobari et al. 2014).

To our knowledge, this is the first study that has examined changing socioeconomic disparities in obesity among preschool-aged children living in low-income households. Although socioeconomic disparities exist among these children (CDC 2014), trends and disparities in obesity among this population have until now mainly focused on differences by race/ethnicity (Pan et al. 2015, Sekhobo et al. 2013, Weedn et al. 2014). A strength of this study is the use of neighborhood SES in addition to household SES. Most studies that have examined changing socioeconomic disparities in childhood obesity have only used household-level socioeconomic indicators. The study also used measured heights and weights that have previously been validated (Crespi et al. 2012). Finally, the study's large sample size enabled us to have four categories for each SES measure.

The study does have a few limitations. It is a cross-sectional study. Information on individual WIC-participating families' exposure to the impact from the economic recession was not available. These findings may not be generalizable to low-income preschool-aged children in other parts of the U.S. While we examined various transformations of year for the multivariate analyses, having year as a binary 5-year time period may not be the best. Although it provided the flexibility necessary to model the increases in obesity up until 2008 separately from the decreases after 2010, it did not allow for the modeling of any potential differences in the effect of SES on obesity during the 5-year time periods.

Conclusion

Socioeconomic disparities in obesity among vulnerable low-income preschool-aged children in Los Angeles County exist. In the years following the economic recession, the disparities in obesity by household-level SES widened among these children while the disparities by neighborhood-level SES did not change. Future research should examine the factors responsible for the widening household-level disparities in obesity. Continuing efforts should be made to address socioeconomic disparities in early childhood obesity.

CHAPTER 6: Severe housing cost burden and obesity in preschool-aged low-income children in Los Angeles County

Los Angeles has the highest rates of unaffordable housing in the nation (Joint Center for Housing Studies 2015). In 2013, 48% or more than 2 million of all households in the Los Angeles-Long Beach-Anaheim metro area spent more than 30% of their income on housing, with more than half being “severely burdened” by housing costs, that is spending more than 50% of their income on housing (Joint Center for Housing Studies 2015). Low-income households are disproportionately burdened by housing costs (Joint Center for Housing Studies 2014). Between 2009 and 2011, more than 75% of low-income renters in Los Angeles were severely burdened by housing costs (Ray, Ong and Jimenez 2014). Nearly half a million affordable homes are needed in Los Angeles County to just meet the needs of low-income households (California Housing Partnership Corporation 2014).

Since housing is a basic human need and essential for well-being, financial difficulty to pay for housing may be a risk factor for health. There is a dearth of research on unaffordable housing as a health risk factor (Harkness and Newman 2005, Ma, Gee and Kushel 2008a, Pollack, Griffin and Lynch 2010), and little is known about the impact of unaffordable housing on obesity among low-income preschool-aged children, a vulnerable population which experiences high rates of obesity. The objective of this study is to examine the contribution of unaffordable housing to early childhood obesity risk among low-income families.

Since empirical evidence on the relationship between unaffordable housing and childhood obesity is lacking, this study primarily drew on the Family Stress Model of Economic Hardship, the Risky Families Model and biological theory of the adverse influence of chronic stress on energy balance through the hypothalamic–pituitary–adrenal axis (Bjorntorp 2001, Conger, Rueter and Conger 2000, Conger et al. 2002, Repetti, Taylor and Seeman 2002) to inform how unaffordable housing might influence early childhood obesity. Two mechanisms involving the impact of unaffordable housing on financial resources and parent's chronic psychosocial stress are posited.

First, unaffordable housing may adversely affect the behaviors that increase childhood obesity risk, namely diet and physical activity. When a family has a difficult time paying for housing, they are likely to be at greater risk for food insecurity, relying more heavily on cheap, processed, highly caloric food (Darmon and Drewnowski 2015, Harkness and Newman 2005, Joint Center for Housing Studies 2014, Kirkpatrick and Tarasuk 2011). They are also more likely to live in disadvantaged and unsafe neighborhoods where access to affordable, healthy foods and facilities for exercise and play are limited (Joint Center for Housing Studies 2014, Lovasi et al. 2009, Morland et al. 2002, Schreier and Chen 2013).

Second, the financial strain of not being able to meet housing costs every month can be a chronic stressor for parents. Chronic psychosocial stress occurs when demands from the social environment tax a person's ability to adapt to the demands causing "psychological and biological changes that may place a person at risk for disease" (Baum, Cohen and Hall 1993, Cohen, Kessler and Gordon 1995). It may lead to conflict in the home environment and be detrimental to a parent's mental health, creating a cold, unsupportive and neglectful home environment for the child (Davison, Jurkowski and Lawson 2013), and affecting the quality of care and resources a child receives (Thompson 2014). It may result in insecure attachment of the child with his/her primary caregiver (Thompson 2014), leading to dysregulation of the child's biological stress response system and disrupting energy metabolism (Anderson and Whitaker 2011, Garasky et al. 2009, Gunnar and Quevedo 2007, Thompson 2014, Wilson and Sato 2014) Indeed, a stressful home environment has been found to dysregulate a child's hypothalamic-pituitary-adrenal (HPA) axis thereby increasing the child's risk of developing obesity (Bjorntorp 2001, Lumeng et al. 2014, Miller et al. 2013, Repetti, Taylor and Seeman 2002).

Financial stressors are risk factors for parent's mental health, and a mother's chronic stress and depression during infancy and preschool years have been observed to be associated with increased risk of childhood obesity (Lampard, Franckle and Davison 2014, Tate et al. 2015). Parents who are chronically stressed may have less energy to cook meals for their children; inexpensive highly-caloric fast food becomes a convenient substitute for home-cooked meals (Parks et al. 2012). The more stressors low-income parents experience, the less likely they are to limit their children's screen time such as watching TV and playing computer games which are established risk factors for childhood obesity (Dennison, Erb and Jenkins 2002, Lampard, Jurkowski and Davison 2013, Lundahl et al. 2013, Rey-Lopez et al. 2008, Swinburn and Shelly 2008).

Based on these posited mechanisms, we ask the following research questions*:*

Is perceived unaffordable housing, defined as severe housing cost burden, associated with increased risk of obesity in low-income preschool-aged children, after controlling for individual-, household- and neighborhood-level confounders such as child's age, mother's education, and neighborhood median household income? Is it also associated with increased adiposity, defined as an increase in BMI z-scores (BMIz) and an increase in weight-for-height z-scores (WHZ) between two time points, in low-income preschool-aged children? If so, does perceived unaffordable housing increase adiposity in these children through child's diet and sedentary behavior, and mother's mental health?

<u>Hypothesis 1</u>: Severe housing cost burden is associated with an increased risk of obesity, as indicated by weight status (obese vs not obese), in low-income preschool-aged children.

Hypothesis 2: Severe housing cost burden is associated with an increased risk of obesity as indicated by change in adiposity in low-income preschool-aged children.

Hypothesis 3: The association between severe housing cost burden and change in adiposity is partially mediated by child's diet, sedentary behavior, and mother's mental health.

Methods

Overview

This study uses data from the 2011 and 2014 Los Angeles County WIC Survey ("WIC Survey"), WIC administrative data, and 2010 Census data to examine the relationship of severe housing cost burden with obesity risk during the early years of life in a low-income population.

Data sources

Initiated in 2005 and funded by First 5 LA, the WIC Survey is commissioned by Public Health Foundation Enterprises (PHFE) and conducted every three years by Field Research Corporation, an independent public opinion research organization (PHFE-WIC and First 5 LA 2015). The survey is conducted on a random sample of approximately 6,000 WIC participants in Los Angeles County to determine health status, health behaviors, health care access, and neighborhood and household characteristics of children of families participating in WIC. Many of the survey questions have either been validated or come from validated instruments, and data from these surveys have been analyzed and published on a number of topics including determinants of children's fruit and vegetable consumption, breastfeeding, and mother's perception of child's weight (Chaparro et al. 2015, Langellier et al. 2014, Nobari, Wang and Whaley 2015).

A random sample of WIC participants is drawn from the main cross-section sample and from an augmented sample of WIC participants in Antelope Valley, the least populated area in

Los Angeles County (Field Research Corporation 2014). In 2011 and 2014, additional participants were randomly selected from First5 LA's smaller Best Start communities and in 2011, children of Asian mothers were also oversampled (Field Research Corporation 2014). Phone interviews were conducted in the spring and summer months in English, Spanish, and in 2011 also in Vietnamese and Cantonese. Computer-assisted telephone interviewing was used to conduct the interviews. Up to 16 attempts were made to reach the respondent. Households received a $10 gift card for completing the interview. The survey protocol was approved by the Independent Review Consulting Institutional Review Board. More information on the survey can be found at http://lawicdata.org/survey/.

Survey records were linked to WIC administrative data to obtain children's measured anthropometric data, date of birth, family socioeconomic information and census tract of residence. The WIC administrative data are owned by the State of California WIC Program and maintained by the WIC Data Mining project, a research partnership between Public Health Foundation Enterprises-WIC (PHFE WIC) and First 5 LA. Children's anthropometric information is obtained during clinic visits by trained WIC staff who follow a standardized protocol. Wall-mounted stadiometers (Model PE-WM-60-76; Prospective Enterprises, Portage, MI) and calibrated beam scales (Health-O-Meter 402LB; Prospective Enterprises, Portage, MI) are used to measure children's heights and weights, respectively. A healthcare provider's measurements can instead be used if the child was examined within 60 days of his/her WIC visit (Crespi et al. 2012). Measurements obtained by PHFE-WIC staff on preschool-aged children in Los Angeles County have high validity (Crespi et al. 2012).

To characterize child participants' neighborhood conditions, survey records were also linked to the Census Bureau's 2010-2014 American Community Survey (ACS) data through the child's census tract of residence.

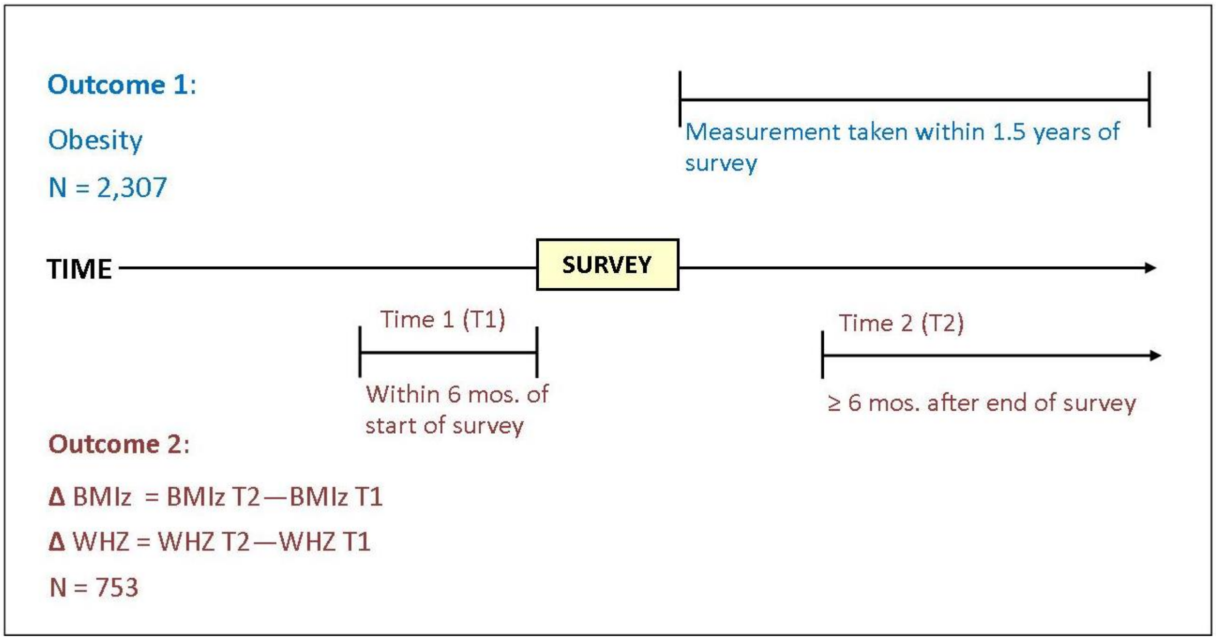
Variables

Dependent Variables

Obesity risk was assessed by two indicators: (1) obesity status (obese vs not obese), and (2) change in adiposity (body fatness) between two time points. While there is no current consensus on the appropriate definition and measurement of obesity in very young children, obesity in children is generally defined as having a BMI that is $\geq$ 95th percentile of sex- and age-specific growth reference values (Kuczmarski et al. 2002), while adiposity (a continuous variable) is measured by BMI or weight-for-height (WH) expressed in terms of z-scores derived from growth reference values (Kuczmarski et al. 2002). Though BMIz is more commonly used in the literature, it has been argued that WHZ is a preferred measure of obesity in young children since it is less dependent on height than BMIz (Garn, Leonard and Hawthorne 1986, Jones et al. 2012).

In this study, children were classified as *obese* if they had a BMI ≥ 95th percentile of CDC's sex- and age-specific growth reference values (Kuczmarski et al. 2002). *Change in BMI z-score (ΔBMIz)* and *change in weight-for-height z-score (ΔWHZ)* were calculated from two measurements, the first (T1) taken no earlier than 6 months before the survey interview, and the second (T2) taken at least 6 months after the survey interview. The conditions for these two time points were set to ensure that the first measurement was close enough to the survey to capture the effect of severe housing cost burden, and the second measurement was distant enough from the first measurement to allow for a change in adiposity to occur. (See Figure 6.1 for a depiction of the times the measurements occurred.) (See Tables C1 & C2 in Appendix for a table of the variables used in this study and the related questions from the WIC survey).

Figure 6.1. Time when outcome measures (obesity and change in BMIZ or WHZ) were taken in relation to the survey



ΔBMIz=change in BMIz
ΔWHZ=change in WHZ

Independent Variables

The independent variable of interest is perceived *severe housing cost burden* as determined by the response of "very difficult" to the question, "How easy or difficult is it for you to pay for housing—very difficult, somewhat difficult, somewhat easy or very easy?" Since the majority of families experienced some difficulty, a binary yes versus no variable was created to measure those reporting extreme housing costs (very difficult to pay for housing).

Mediating Variables

The mediating variables were child's healthy and unhealthy diet as determined by f*ruit and vegetable consumption* and an *unhealthy food score*, *screen time* and *mother's depressive symptoms*. *Fruit and vegetable consumption* is the number of servings of fruits and vegetables that the child eats on an average day. Extreme outliers were coded as missing. For mediation analysis this variable was treated as continuous. However, for descriptive purposes, three categories were created based on dietary recommendations for young children (USDA 2015) and the sample's distribution: ≤ 2 servings per day, 3-4 servings per day, and ≥ 5 servings per day. An *unhealthy food score* was created based on fast food frequency, sweet food frequency and sugar-sweetened beverage (SSB) frequency. Child's *fast food frequency* is a categorical variable and the five response categories varied from never to 4 or more times per week. *Sugar-sweetened beverages* is the number of times per day the child drinks sugar-sweetened beverages (SSB) (sweetened milk, non-100% juice intake, sweetened drink intake and soda intake). *Sweet foods* is the number of times per day the child eats sweets or sweetened foods, such as sweetened cereals, fruit bars, pop-tarts, donuts, cookies and candies. The food frequency questions were recently validated with a 24 hour-diet recall study. Spearman's correlation coefficients ranged from 0.15 to 0.59 and intraclass correlation coefficients ranged from 0.48 to 0.87 (Koleilat and Whaley 2016).

To create the unhealthy food score, fast food, sweet foods and SSB per day were dichotomized according to recommendations for children and the sample's distribution (Barlow 2007, Daniels and Hassink 2015). Consumption of fast food at least once a week, of a SSB at least once a day, and of a sweet food at least once a day were each given a score of 1. The scores were summed to create an unhealthy food score and ranged from 0 to 3. The score was found to be strongly correlated with each of the 3 unhealthy food indicators (0.737 for fast food, 0.721 for SSB, and 0.672 for sweet foods, all p-values <0.001), and the 3 unhealthy food indicators had small positive correlations with each other (r ranged from 0.2 to 0.3) (see Table 5.3).

Screen time is a continuous variable of the total number of hours reported by the parent that the child spends watching TV and playing video or computer games on an average day. A dichotomous variable of two or more hours a day based on recommendations for young children was also examined (AAP Committee on Public Education 2001, Barlow 2007).

Mother's depressive symptoms is an index representing the mother's frequency of experiencing anhedonia (no pleasure) and depressed mood in the last two weeks. It was determined by the two-item Patient Health Questionnaire (PHQ-2) which has been shown to have high sensitivity and specificity for major depression (Kroenke, Spitzer and Williams 2003). The responses were scored and summed. A score of 3 or higher is considered depression. For the mediation analysis, this was treated as pseudo-continuous.

Covariates

The analyses controlled for variables that have been found to be associated with obesity (Kit, Ogden and Flegal 2014, Linabery et al. 2013, Wang and Zhang 2006). *Child's age* at two time points were used for this study (at T1 and at the time of the survey). Both are continuous variables, in months, and were calculated from the child's date of birth (caregiver-reported and obtained from the WIC administrative data) and the relevant measurement date. *Child's gender* was obtained from the WIC Survey. *Child's race/ethnicity* was created from a question on race and from a question regarding Latino or Hispanic ethnicity that is asked of the respondent. The categories were Hispanic, Non-Hispanic (NH) white, NH black, NH Asian, and NH multiple race. Four dummy variables were created with Hispanic as the reference group since the majority of children are Hispanic. Since the sample size to examine the association of severe housing cost burden and change in adiposity was much smaller, only child's Hispanic ethnicity was considered and this was a dummy variable with Hispanic as the reference group.

To examine the association of severe housing cost burden with change in adiposity, *child's BMIz or WHZ at T1* was adjusted for in the analyses to account for child's initial weight. For all of the analyses, the duration between two time points (in months) is adjusted for to account for the variation in duration among children. In examining the association between severe housing cost burden and obesity, the duration is the number of months between when the survey was conducted and when the height and weight measurements occurred. In examining the association between severe housing cost burden and change in BMIz or WHZ, the duration is the number of months between T1 and T2.

Mother's BMI is a continuous variable and was calculated from mother's self-reported height and weight [BMI=weight (kg) / [height (m)]^2]. *Mother's education* indicates the highest level of school she completed or highest degree received (less than high school, high school, some college or more). *Household income* is an ordinal variable and represents the percent of the Federal Poverty Level (FPL) of the household (as ≤50% FPL, 50.1-100% FPL%, 100.1-133% FPL, and 133.1-185+% FPL). It is calculated by dividing the household's monthly income by the number of people in the household. Income is obtained from the WIC administrative dataset and includes every household member's income from all sources such as wages, unemployment compensation, social security benefits, State Disability Insurance, public assistance, and child support.

Since the socioeconomic characteristics of the neighborhood may confound the relationship between unaffordable housing and child obesity, the neighborhood-level indicator, *median household income*, was examined as a potential covariate. The measure comes from the American Community Survey and represents the 5-year estimate of the median household income of residents living in the child's census tract and was treated as a continuous variable. Data from the two surveys were pooled to increase sample size, therefore, a binary y*ear of survey* variable (2011 vs 2014) was added to account for any potential differences by survey year.

Potential confounders and moderators

Food insecurity, housing tenure, household size, and number of moves were explored as potential confounders and moderators since they have been found to be associated with childhood obesity and well-being, unaffordable housing, or the potential mediators (Cutts et al. 2011, Eisenmann et al. 2011, Evans 2004, Herbert, McCue and Sanchez-Moyano 2013, Kirkpatrick and Tarasuk 2011, Leventhal and Newman 2010, Mason et al. 2013, Pollack, Griffin and Lynch 2010). *Food insecurity* is a dichotomous variable (food insecure vs. food secure) that was determined by the 6-item short form of the USDA's household food security scale. The scale has been shown to have high specificity and sensitivity, however, it does not measure severe food insecurity where the child's food intake is affected (USDA ERS 2012). *Housing tenure* represents where the respondent lives (in a home owned by parents or relatives, in an apartment or home that the respondent owns, in an apartment or home that the respondent rents, or other). Both a continuous *household size* variable that represents the number of people currently living in the household was explored as a potential confounder as well as a dichotomous variable of households with 5 or more people. *Number of moves* is a continuous measure that represents the number of moves in the past 3 years the household experienced. A dichotomous variable of 2 or more moves was also examined.

Statistical Analysis

To examine the association of severe housing cost burden and obesity, children had to be at least 2 years old at the time of the survey. To examine the association of severe housing cost burden and change in adiposity, children had to be at least 2 years at T1 to be included in the study. Children who had grown shorter between measurements or with biologically implausible values of BMIz or WHZ < -4 or > 8, or weight-for-age z-scores or height-for-age z-scores < -3 or > 5 (CDC 2016) were excluded. Children whose biological mothers did not respond to the survey, mothers with improbable BMIs (< 15 kg/m^2 or > 56 kg/m^2), or who were missing on any of the covariates, potential mediators and potential moderators were also excluded. The final sample size was 2,307 to examine the association of severe housing cost burden and obesity, and 795 to examine the association between severe housing cost burden and change in BMIz or WHZ.

Univariate and Bivariate Analyses

Means and standard deviations and frequency distributions were used to examine the distribution of continuous and categorical variables, respectively. The outcome variables, change in BMIz and change in WHZ, were found to be normally distributed. Bivariate statistics were used to investigate the relationship of the independent variable and the dependent variables with each other and with the covariates. Student's t-test were used to determine whether a statistically significant relationship exists between severe housing cost burden and the continuous variables. For categorical variables, Pearson chi-square tests were used. Pearson correlation coefficients were used to assess the linear relationship between continuous variables. Spearman's and Polychoric's correlation coefficients were used for ordinal variables and Tetrachoric correlation coefficients were used for two dichotomous variables.

Multivariate Analyses

To examine the association of severe housing cost burden and obesity, multiple logistic regression analyses were conducted. To examine the association of severe housing cost burden with change in BMIz or WHZ, multiple linear regression using ordinary least squares was conducted. Logistic and linear regression analyses were adjusted for child's age, gender, race/ethnicity, household income, mother's BMI and education, neighborhood median household income, year of survey, and duration. When examining change in BMIz or WHZ as the outcome, the analyses were also adjusted for BMIz or WHZ at T1. The t-test statistic was used to assess whether each regression coefficient was significantly different from zero (Glantz and Slinker 2001). Overall model fit was determined by the F statistic and adjusted R^2 (Glantz and Slinker 2001). Regression diagnostics were conducted to examine normality, homoscedasticity, independence, influential observations, and collinearity, and appropriate steps were taken to address any issues. Food insecurity, mother's depression, household size, housing tenure, and multiple moves were explored as potential confounders and/or moderators.

Mediation Analysis

Child's diet (fruit and vegetable consumption and the unhealthy food score), screen time, and mother's depressive symptoms were each examined for their potential mediating roles in the relationship between severe housing cost burden and change in adiposity. A mediator represents the hypothesized causal mechanism by which the independent variable, X, influences the dependent variable, Y (Aneshensel 2013). A diagram of simple mediation, with one mediator, can be seen in Figure 6.2.

Baron and Kenny's four criteria are not necessary to determine mediation (Aneshensel 2013). Instead, two conditions are necessary in order to have mediation: 1) X must be significantly associated with the mediator, M; and 2) M must be significantly associated with Y after controlling for X (Aneshensel 2013). In Figure 6.2, the total effect of X on Y, ***c***, consists of the direct effect of X on Y, **c'**, and the indirect effect through M, ***a*b = c- c'***. The regression coefficients obtained from the three linear regression models in Figure 6.2 were used to estimate the mediated effect, a*b, of each potential mediator on severe housing cost burden (Aneshensel 2013). Each of the linear regression models controlled for the previously mentioned covariates.

All analyses were either conducted in SAS versions 9.3 or 9.4 (SAS Institute, Cary, NC). Given that the sampling distribution of a*b is not normal, the SAS macro PROCESS developed by Andrew Hayes and which uses a bootstrapping method, was used to determine the mediated effects, the standard errors and confidence intervals (Hayes 2009, Hayes 2015). Since mediation of categorical mediators cannot be done in SAS, the unhealthy food score and mother's depression were treated as pseudo-continuous. Tests for statistical significance were based on a p-value < 0.05.

Figure 6.2. Simple mediation

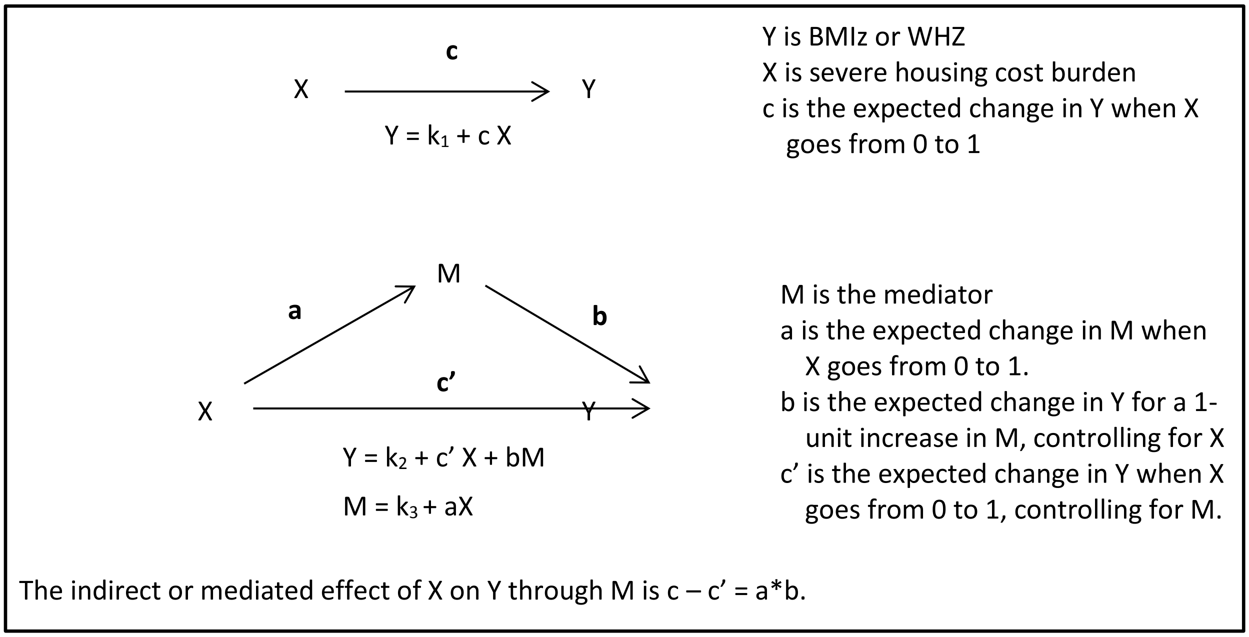


Figure adapted from Aneshensel 2013

Results

In our larger sample, the mean (SD) age of children was 3.1 (0.7) years and there were slightly more boys than girls (Table 6.1). The majority of children were Hispanic (87.5%). Nearly 36% of children's mothers had less than a high school degree and a third had at least some college. Nearly 78% of children lived in poor households, with 30% of them living in extreme poverty (≤ 50% FPL). Mothers' mean (SD) BMI was 28.6 (6.1) kg/m^2. Children's mean (SD) neighborhood median household income was $43,116 (15,372), which is notably lower than the average for Los Angeles County ($55,870 in 2014 dollars) (U.S. Census Bureau 2016). A little over a third of children were from the 2011 WIC Survey with the remaining two-thirds being from the 2014 survey.

In the sample, 15.9% of children lived in severe housing cost-burdened households. These children were significantly less likely to be Hispanic, and were significantly more likely to have mothers with less than a high school education and to live in extremely poor households (≤ 50% FPL) than children living in non-severe housing cost-burdened households. Their mothers were also significantly more likely to have participated in the 2011 WIC Survey.

Table 6.1. Sociodemographic characteristics of the sample of 2-5-year-old children by severe housing cost burden: Los Angeles County, 2011 and 2014 WIC Survey, N=2,307

	Total (N=2,307) Mean (SD) or %	Not severe housing cost burden (N=1,940) Mean (SD) or %	Severe housing cost burden (N=367) Mean (SD) or %
Child's age at survey (yrs)	3.1 (0.7)	3.1 (0.7)	3.2 (0.6)
Child's gender (female)	47.7%	47.8%	47.1%
Child's race/ethnicity			
NH white	2.5	2.3	3.3*
NH black	6.8	6.6	7.6
NH Asian	1.7	1.8	1.1
Hispanic	87.5	88.0	84.7
NH multiple race	1.6	1.3	3.3
Mother's education			
Less than high school	35.9%	35.3%	39.5%**
High school	30.8%	32.1%	23.7%
Some college or more	33.3%	32.6%	36.8%
Mother's BMI (kg/m^2)	28.6 (6.1)	28.6 (6.1)	28.8 (6.2)
Household income			
≤ 50% FPL	30.0	27.8	41.7***
50.1-100% FPL	47.9	48.7	43.6
100.1-133% FPL	12.7	13.5	8.7
133.1-185% FPL	9.4	10.0	6.0
Neighborhood median household income ($)	$43,116 (15,372)	$43,116 (15,408)	$43,117 (15,200)
Months from survey to time of measurement	5.9 (2.7)	5.9 (2.7)	5.9 (2.7)
2011 survey year	35.1%	34.1%	40.1%*

Chi-Square test or t-test of differences by severe housing cost burden: *p-value <0.05; **<0.01; ***<0.001
NH = Non-Hispanic; FPL= Federal Poverty Level
Mother's BMI based on self-report of height and weight

Nearly 18% of the children in the sample were obese (Table 6.2). Children living in severe housing cost-burdened households were significantly more likely to be obese compared to children living in non-severe housing cost-burdened households (21.5% vs. 17.1%, p-value = 0.040). For the smaller sample of 753 children, the mean (SD) changes in BMIz and WHZ were 0.013 (0.751) and -0.074 (0.687), respectively. No statistically significant differences existed by severe housing cost burden.

Nearly two-thirds of the children in our larger sample met the recommendation of 5 or more servings of fruits and vegetables per day (Table 6.2). A little over half ate fast food at least once a week, almost two-thirds drank a SSB per day, three quarters ate at least one sweetened food per day, and a third of all children did all three of these. A little over half of all children were exposed to at least 2 hours per day of screen time (watching TV and/or playing computer games). No statistically significant differences existed by severe housing cost burden for screen time or for children's diet except for consumption of sweet foods (1.1 vs 1.0 times/day, p-value = 0.025), though perhaps not meaningfully different.

Table 6.2. Health behaviors of the sample of 2-5-year-old children by severe housing cost burden: Los Angeles County, 2011 and 2014 WIC Survey, N=2,307

	Total (N=2,307) Mean (SD) or %	Not severe housing cost burden (N=1,940) Mean (SD) or %	Severe housing cost burden (N=367) Mean (SD) or %
% obese[1]	17.8%	17.1%	21.5%*
Change in BMIz (N=753)	0.013 (0.751)	0.014 (0.762)	0.004 (0.691)
Change in WHZ (N=753)	-0.074 (0.687)	-0.070 (0.696)	-0.098 (0.637)
Fruit and vegetable (servings/day) (cont)	5.4 (2.2)	5.4 (2.2)	5.2 (2.2)
Fruit and vegetable consumption			
≤ 2 servings/day	6.4%	6.2%	7.6%
3-4 servings/day	29.9%	29.6%	31.6%
≥5 servings/day	63.7%	64.2%	60.8%
Fast food[2]			
< 1 a month	12.8%	12.5%	14.4%
Less than once a week but at least once a month	33.9%	34.3%	31.9%
≥ 1 time per week	53.3%	53.2%	53.7%
SSB (times/day) [3]	1.4 (1.6)	1.4 (1.6)	1.5 (1.7)
SSB			
< 1 (times/day)	37.4%	38.0%	34.1%
≥ 1 (times/day)	62.6%	62.0%	65.9%
Sweet foods (times/day) [4]	1.0 (0.8)	1.0 (0.8)	1.1 (0.8)*
Sweet foods			
< 1 day	25.2%	25.8%	22.3%
≥ 1 day	74.8%	74.2%	77.7%
Unhealthy food score[5]			
0 (not unhealthy)	8.6%	8.9%	7.1%
1	24.7%	25.3%	21.8%
2	34.0%	33.3%	37.9%
3 (very unhealthy)	32.6%	32.5%	33.2%
Screen time (hours/day)[6] (cont)	1.8 (1.6)	1.8 (1.6)	1.9 (1.5)
Screen time			
< 2 hours/day	46.9%	47.4%	44.4%
≥ 2 hours/day	53.1%	52.6%	55.6%

Chi-Square test or t-test of differences by severe housing cost burden: *p-value <0.05; **<0.01; ***<0.001

[1]Obesity is a BMI ≥ 95th percentile of CDC's gender- and age-specific growth reference values

[2]Fast food is a restaurant like McDonald's, Taco Bell, Burger King, KFC or another similar place

[3]SSBs are sweetened milk, non-100% juice, sweetened drinks and sodas

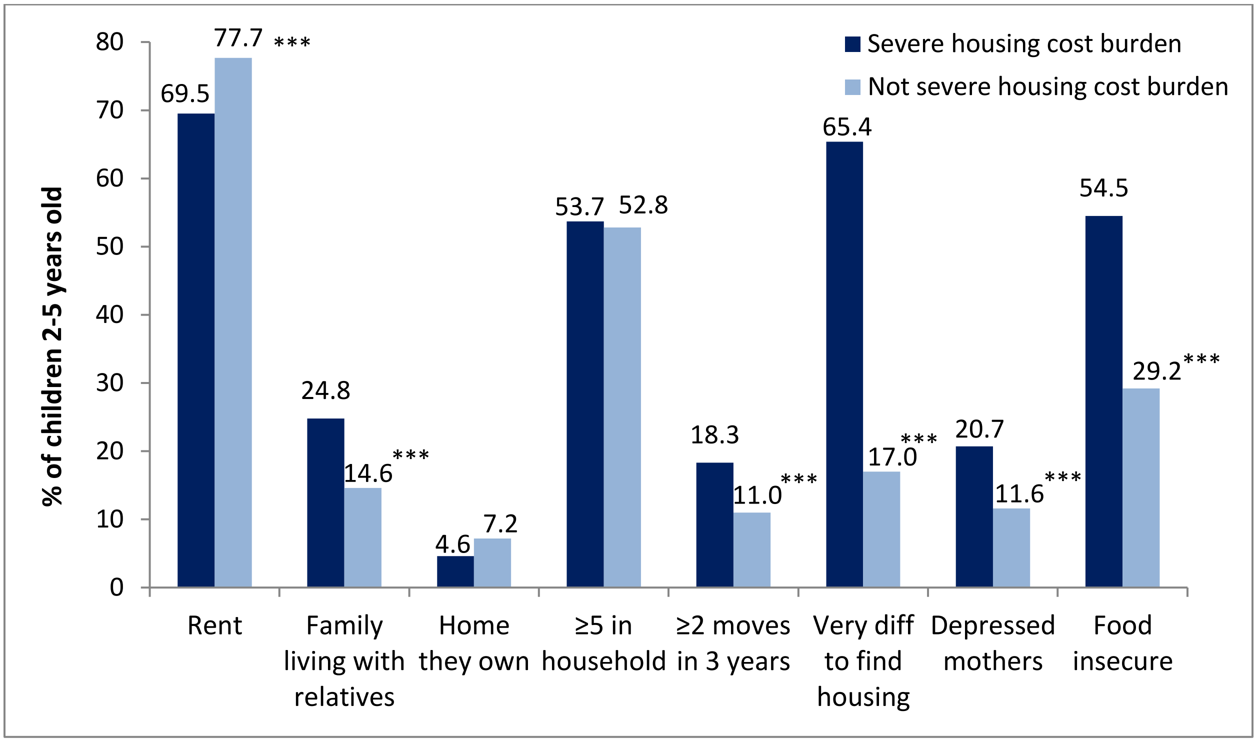
[4]Sweet foods include sweets or sweetened foods such as sweetened cereals, fruit bars, pop-tarts, donuts, cookies and candies

[5] Based on eating fast food at least once a week, drinking a SSB at least once a day, and eating a sweet food at least once a day.

[6]Screen time includes television and video or computer games

Severe housing cost-burdened households were significantly less likely to rent and more likely to live with parents or relatives than non-severe housing cost-burdened households, although the mean number of people living in the households was similar (Figure 6.3). Children living in severe housing cost-burdened households were significantly more likely than their advantaged counterparts to live in a stressful home environment, characterized by moving 2 or more times in the last three years and/or having a mother who was depressed (Figure 6.3). They were also significantly more likely to live in households that were food insecure and that had trouble finding housing (Figure 6.3).

Figure 6.3. Home environment of 2-5-year-old children by severe housing cost burden in Los Angeles County, 2011 and 2014 WIC Survey, N=2,307



Chi-Square test of differences by severe housing cost burden: *p-value <0.05; **<0.01; ***<0.001

The correlation coefficients for the relationships between some of the main variables are in Table 6.3. Many of the coefficients were small. Of note, are the correlations between the diet measures, the correlation of severe housing cost burden and mother's depression ($r = 0.250$, $p < .001$), and the correlation of unhealthy food score and screen time ($r=0.207$, p-value $< .001$).

Table 6.3. Table of correlation coefficients (N=2,307)

	Severe housing cost burden	Obesity	Child's age at survey	Mother's education	House-hold income	Neighb. Median House-hold income	Fruit/ Vegetable	Unhealthy Food score	Fast food	Sweet foods	SSB	Mother's depres-sion (PHQ-2)	Screen time
Severe housing cost burden	---	R(ASE)[a]= 0.091 (.045)	0.032	-0.001	-0.191 ***	0.000	-0.023	0.046	0.003	0.047*	0.039	0.250***	0.008
Obesity		---	0.658 ***	-0.061	0.024	0.119	-0.0001	0.056	0.063	-0.054**	0.024	0.013	-0.014
Child's age at survey			---	-0.088 ***	0.013	0.003	0.029	0.111***	0.091***	0.028	0.074 ***	-0.008	0.123 ***
Mother's educ				---	0.120***	0.086***	0.055**	-0.121***	-0.049	-0.059**	-0.157 ***	-0.126 ***	0.045*
Household income					---	0.099***	-0.025	-0.222	0.055*	-0.055**	-0.101 ***	-0.097 ***	-0.042*
Neighb. Median Household income						---	0.001	-0.056**	-0.009	-0.019	-0.053*	-0.031	-0.021
Fruit/ Vegetable							---	-0.072***	-.079***	0.004	-0.024	-0.013	-0.077 ***
Unhealthy Food score								---	0.737***	0.672***	0.721***	0.157***	0.207***
Fast food									---	0.217***	0.231***	0.062*	0.143***
Sweet foods										---	0.330***	0.126***	0.153***
SSB											---	0.187***	0.165***
Mother's depression												---	0.096***
Screen time													---

p-value of Wald Chisquare test * < 0.05; ** < 0.01; *** < 0.001

Correlation coefficients are [a] Tetrachoric (for two dichotomous variables), Pearson's (for two continuous variables, and one continuous and dichotomous), Spearman's (for one ordinal and one continuous), and Polychoric (for two ordinal variables, for one ordinal and one dichotomous, or for one ordinal and one continuous).

Multivariate analyses examining association of severe housing cost burden and childhood obesity

Living in severe housing cost-burdened households was associated with a 33% higher odds of obesity [OR (95%CI) = 1.33 (1.01; 1.76)] (see Model 1 in Table 6.4). There was no change in the relationship after adjusting for child's age, gender and race/ethnicity, mother's education and BMI, household income, duration between survey and outcome, and survey year (Model 2), nor after adjusting for neighborhood median household income as well (Model 3).

With regard to the covariates, as shown in Model 2, child's age at survey was significantly associated with increased odds of obesity such that a one-year increase in age increased the odds of obesity by 28%. Being NH black decreased the odds of childhood obesity by 61% compared to being Hispanic [OR (95%CI) = 0.39 (0.22; 0.70)]. Every 1 kg/m^2 increase in mother's BMI was significantly associated with a 7% increase in the odds of obesity.

Mother's depression, food insecurity, residence type, household size, and number of moves were included in the models and explored as potential moderators of the relationship [results not shown]. Household size was found to be significant. The association between severe housing cost burden and childhood obesity was no longer significant at a $p\text{-value} < 0.05$ after controlling for household size (Model 4), although it was borderline significant ($p=0.054$). An increase of 1 person in the household was associated with an 8% decrease in the odds of obesity [OR (95%CI) = 0.92 (0.86; 0.99)]. For each additional person in the household, the log odds of the effect of severe housing cost burden on obesity increases by 0.236 ($p=0.01$).

Table 6.4. Logistic regression models: association between severe housing cost burden and obesity, 2011 and 2014 WIC Survey (N=2,307)

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Severe housing cost burden (Not severe housing cost burden, ref)	**1.33 (1.01, 1.76)**	**1.334 (1.002, 1.776)**	**1.334 (1.002, 1.776)**	1.326 (0.995, 1.767)
Child's age at survey (yrs)		**1.28 (1.08, 1.51)**	**1.28 (1.08, 1.51)**	**1.27 (1.08, 1.51)**
Child's gender (boy, ref)		0.84 (0.67, 1.05)	0.84 (0.67, 1.04)	0.83 (0.67, 1.04)
Child's race/ethnicity (Hispanic, ref)				
NH black		**0.39 (0.22, 0.70)**	**0.40 (0.22, 0.71)**	**0.38 (0.21, 0.67)**
NH Asian		0.55 (0.17, 1.81)	0.53 (0.16, 1.76)	0.54 (0.16, 1.79)
NH white		0.59 (0.25, 1.42)	0.58 (0.24, 1.39)	0.58 (0.24, 1.38)
NH multiple		1.20 (0.53, 2.71)	1.21 (0.53, 2.72)	1.17 (0.52, 2.66)
Mother's education (Some college, ref)				
Less than high school		1.11 (.85, 1.46)	1.12 (.85, 1.48)	1.16 (.88, 1.52)
High school		1.10 (0.83, 1.46)	1.11 (0.84, 1.47)	1.12 (0.85, 1.49)
Household income (133-185+% FPL, ref)				
<50% FPL		0.89 (0.58, 1.37)	0.90 (0.59, 1.39)	0.93 (0.60, 1.43)
50-100% FPL		1.01 (0.68, 1.52)	1.02 (0.68, 1.53)	1.04 (0.69, 1.56)
100-133% FPL		1.18 (0.74, 1.89)	1.18 (0.73, 1.89)	1.20 (0.75, 1.93)
Mother's BMI (kg/m^2)		**1.07 (1.05, 1.09)**	**1.07 (1.05, 1.09)**	**1.07 (1.05, 1.09)**
Time between survey and T2 (mos)		1.00 (0.96, 1.04)	0.99 (0.95, 1.04)	1.00 (0.96, 1.04)
Survey year 2011 (2014, ref)		1.08 (0.86, 1.36)	1.07 (0.85, 1.35)	1.10 (0.87, 1.38)
Household size			——	**0.92 (0.86, 0.99)**
Median household income (in $10,000)			1.03 (0.96, 1.11)	

NH = Non-Hispanic; FPL= Federal Poverty Level; ref=Reference
Mother's BMI based on self-report of height and weight

Multivariate analyses examining association of severe housing cost burden and change in adiposity

Adjusting for child's age, gender and race/ethnicity, mother's education and BMI, household income, BMIz at T1, time interval between T1 and T2, and survey year, living in severe housing cost-burdened households was not significantly associated with a change in BMIz between T1 and T2 (Model 1 in Table 6.5). There was no significant change in the relationship after adjusting for neighborhood median household income (Model 2).

With regard to the covariates, household income was significantly associated with a smaller change in BMIz between time 1 and time 2. Living in <50% FPL households was associated with a .254 decrease in the change in BMIz (p-value = 0.0146) compared to living in 133-185+% FPL households (Model 1 in Table 6.5). Living in 50-100% FPL households was associated with a .262 decrease in the change in BMIz (p-value = 0.0074) compared to living in 133-185+% FPL households. Living in 100-133% FPL households was associated with a .363 decrease in the change in BMIz (p-value = 0.0018) compared to living in 133-185+% FPL households. A one standard deviation increase in the BMIz at T1 was associated with a .200 decrease in the change in BMIz (p-value < 0.0001). Every 1 kg/m^2 increase in mother's BMI was associated with a .018 increase in the change in BMIz (p-value < 0.0001).

Dichotomous measures of the potential mediators (2 or more hours of screen time, eating at least 5 servings of fruit and vegetables, and mother's depression), in addition to food insecurity, residence type, household size, and number of moves, were also included in the models and explored as potential covariates and moderators. Adjusting for the previously mentioned covariates, watching 2 or more hours of screen time was associated with a .116 decrease in the change in BMIz (p-value =0.032). However, watching 2 or more hours of screen time was not a moderator of the association between severe housing cost burden and childhood obesity.

Similar results were found for WHZ although the coefficients were slightly different. Additionally, based on the adjusted R^2, the models accounted for a greater percentage of the variance for the change in WHZ than they did for the change in BMIz.

Table 6.5. Linear regression models: association between severe housing cost burden and change in BMIz or WHZ between time 1 (T1) and time 2 (T2)[0], 2011 and 2014 WIC Survey, (N=753)

	Change in BMIz			Change in WHZ		
	Model 1 b (SE)	Model 2 b (SE)	Model 3 b (SE)	Model 1 b (SE)	Model 2 b (SE)	Model 3 b (SE)
Severe housing cost burden (Not severe housing cost burden, ref)	.039 (.075)	.041 (.075)	.045 (.074)	.027 (.065)	.029 (.065)	.032 (.065)
Child's age at T1 (yrs)	.072 (.049)	.070 (.049)	.084 (.050)	.070 (.043)	.068 (.043)	.080 (.043)
Child's gender (boy, ref)	-.057 (.053)	-.058 (.053)	-.058 (.052)	-.063 (.046)	-.064 (.046)	-.064 (.046)
Child Non-Hispanic (Hispanic, ref)	.007 (.092)	.005 (.092)	.017 (.091)	.002 (.080)	-.000 (.080)	.010 (.079)
Mother's education (Some college, ref)						
Less than high school	.069 (.065)	.073 (.065)	.065 (.065)	.068 (.057)	.072 (.057)	.065 (.057)
High school	.012 (.066)	.015 (.066)	.015 (.066)	.015 (.058)	.018 (.057)	.018 (.058)
Household income (133-185+% FPL, ref)						
<50% FPL	-.254 (.104)*	-.246 (.104)*	-.246 (.103)*	-.193 (.091)*	-.186 (.091)*	-.186 (.090)*
50-100% FPL	-.262 (.098)**	-.254 (.098)**	-.257 (.097)**	-.202 (.085)*	-.195 (.085)*	-.198 (.085)*
100-133% FPL	-.363 (.116)**	-.360 (.116)**	-.359 (.116)**	-.285 (.101)**	-.282 (.101)**	-.282 (.101)**
Measurement at T1 (BMIz or WHZ)	-.200 (.024)***	-.202(.024)***	-.200 (.024)***	-.264 (.021)***	-.265 (.021)***	-.264 (.021)***
Time between T1 and T2 (mo)	.001 (.014)	-.0001 (.0144)	.002 (.014)	-.007 (.013)	-.007 (.013)	-.006 (.013)
Mother's BMI (kg/m^2)	.018 (.004)***	.018 (.004)***	.017 (.004)***	.015 (0.004)***	.015 (0.004)***	.015 (.004)***
Survey year (2014, ref)	-.011 (.054)	-.014 (.054)	.010 (.055)	-.010 (.047)	-.013 (.047)	.008 (.048)
Median household income (in $10,000)		.014 (.018)			.012 (.016)	
Screen time ≥ 2 hours (<2hrs, ref)			-.116 (.054)*			-.098 (.047)*
F-test	*F (13,739) =6.84****	*F (14,738) =6.39****	*F (14,738) =6.72, ****	*F (13,739) =13.38****	*F (14,738) =12.46****	*F (14,738) =12.79****
R-sq	*.1074*	*.1082*	*.1130*	*.1905*	*.1912*	*.1953*
Adj R-sq	*.0917*	*.0913*	*.0962*	*.1763*	*.1758*	*.1800*

p-value * < 0.05; ** < 0.01; *** < 0.001

[0]T1 ≤ 6 months before survey and T2 ≥ 6 months after survey

NH = Non-Hispanic; FPL= Federal Poverty Level

Mother's BMI based on self-report of height and weight

Analyses examining mother's mental health, and child's diet and screen time as mediators of severe housing cost burden and change in adiposity

Even though severe housing cost burden was not observed to be significantly associated with change in BMIz (or WHZ), it could still have an effect on change in BMIz (or WHZ) solely through the mediators. Neighborhood median household income was excluded from the analyses since it was previously not found to be significant. There was no total effect nor direct effect of living in a severe housing cost-burdened household on change in BMIz, after adjusting for child's age, gender, child's Hispanic ethnicity, mother's education, household income, BMIz measurement at T1, time between T1 and T2, mother's BMI, and survey year (Table 6.6). To determine the indirect effect of severe housing cost burden on change in BMIz through mother's depressive symptoms, the association of severe housing cost burden with mother's depressive symptoms was examined as well as the association of mother's depressive symptoms with change in BMIz controlling for severe housing cost burden. Compared to living in a household that was not severely housing-cost burdened, living in a severely housing cost-burdened household was significantly associated with an increase of 0.527 in mother's depressive symptoms (on the PHQ-2 index), after adjusting for the aforementioned covariates (*a* for mother's depressive symptoms in Table 6.6). Adjusting for severe housing cost burden, a 1-unit increase in the PHQ-2 index was associated with an increase of 0.004 in the change in BMIz, however, this was not statistically significant. From these two linear regression analyses, the indirect effect (95% CI) of severe housing cost burden on change in BMIz through mother's depressive symptoms was .002 (-.018; .026). Since this effect was not statistically significant, mother's depressive symptoms was not a mediator of the relationship between severe housing cost burden and change in BMIz.

The indirect effect (95% CI) of severe housing cost burden on change in BMIz through child's unhealthy diet, fruit and vegetable consumption, and screen time were also not statistically significant (Table 6.6). Therefore, they were not mediators of the relationship between severe housing cost burden and change in BMIz. Similar results were found for change in WHZ.

Discussion

This study found that approximately 16% of WIC-participating preschool-aged children lived in households that were severely burdened with housing costs. Children living in these households were at greater risk of obesity than their counterparts living in households not severely burdened with housing costs. Households severely burdened with housing costs also tended to be exposed to more chronic stressors and to experience more instability than unburdened households. We did not find severe housing cost burden to be associated with change in adiposity, nor did we find child's diet, sedentary behavior, or mother's mental health to mediate the relationship.

Two other studies have examined unaffordable housing and obesity. While these studies did not find a relationship between unaffordable housing and obesity, the studies were of different populations and used different unaffordable housing measures. Garasky et al. (2009) did not find that housing related stressors—an index that included spending >30% of income on housing, doubling up, sending child to live with someone else, and moving to cheaper housing—was significantly associated with overweight and obesity in children 5-17 years old in 2002-2003 (Garasky et al. 2009). It is possible that examining unaffordable housing as part of an index masked its effect. Further, the children participating in this study were older and not from low-income households. The impact of unaffordable housing on obesity risk may be greater in the early years of life when the behavioral risk factors for obesity (namely diet and physical activity levels) are mostly determined by family factors. Additionally, behavioral and mental health effects of unaffordable housing on childhood obesity risk may be felt more keenly by low-income families whose resources are already stretched (Harkness and Newman 2005) and who face a greater threat of becoming homeless if they are not able to pay rent (Ma, Gee and Kushel 2008b).

Table 6.6. Mediating effect of parent's depressive symptoms and child's diet and screen time on the relationship between severe housing cost burden and change in BMIz or WHZ between time 1 (T1) and time 2 (T2)[1], 2011 and 2014 WIC Survey (N=753)

	Mother's depressive symptoms (PHQ-2)[2]		Unhealthy food score[3]		Fruit and vegetable consumption[4]		Screen time[5]	
	change in BMIz b(SE)	change in WHZ b(SE)	change in BMIz b(SE)	change in WHZ b(SE)	change in BMIz b(SE)	change in WHZ b(SE)	change in BMIz b(SE)	change in WHZ b(SE)
c[6]	.039 (.075)	.027 (.065)	.039 (.075)	.027 (.065)	.039 (.075)	.027 (.065)	.038 (.074)	.026 (.065)
c'[7]	.037 (.075)	.025 (.066)	.039 (.075)	.027 (.065)	.038 (.075)	.025 (.065)	.040 (.074)	.028 (.065)
a[8]	.527 (.141)***	.529 (.141)***	-.063 (.099)	-.063 (.099)	-.253 (.236)	-.255 (.236)	.100 (.151)	.101 (.151)
b[7]	.004 (.020)	.005 (.017)	.003 (.028)	.003 (.024)	-.005 (.012)	-.007 (.010)	-.027 (.018)	-.020 (.016)
Total effect (95% CI)	.039 (-.108; .185)	.027 (-.100; .154)	.039 (-.108; .185)	.027 (-.100; .154)	.039 (-.108; .185)	.027 (-.100; .154)	.038 (-.108; .183)	.026 (-.101; .153)
Direct effect (95% CI)	.037 (-.111; .185)	.025 (-.104; .153)	.039 (-.108; .185)	.027 (-.100; .155)	.038 (-.109; .184)	.025 (-.103; .153)	.040 (-.105; .186)	.028 (-.099; .155)
Indirect effect (95% CI)[9]	.002 (-.018; .026)	.002 (-.015; .024)	-.0002 (-.0085; .0053)	-.0002 (-.0088; .0039)	.001 (-.005; .016)	.002 (-.003; .016)	-.003 (-.021; .004)	-.002 (-.017; .003)

p-value * < 0.05; ** < 0.01; *** < 0.001

[a]T1 ≤ 6 months before survey and T2 ≥ 6 months after survey

[b] Mother's frequency of experiencing anhedonia (i.e., no pleasure) and depressed mood in the last two weeks

[c] Based on eating fast food (e.g., Burger King) at least once a week, drinking a SSB (e.g., sweetened milk and non-100% juice) at least once a day, and eating a sweet food (e.g., fruit bars and pop-tarts) at least once a day.

[d]Number of servings per day

[5]Screen time includes television and video or computer games

[6]Obtained from the OLS regression equation: $Y = k_1 + c X$

[7]Obtained from the OLS regression equation: $Y = k_2 + c' X + bM$

[8]Obtained from the OLS regression equation $M = k_3 + aX$

[6,7,8]All models adjusted for child's age, gender, child's Hispanic ethnicity, mother's education, household income, BMIz/WHZ measurement at time 1, time between T1 and T2, mother's BMI, and survey year.

[9]Bias-corrected bootstrap confidence intervals based on a 10,000 bootstrap sample and using Andrew Hayes' process macro

Pollack et al. (2010) also did not find an association between unaffordable housing and obesity, though their study was among adults. While the authors used a similar perceived affordability measure, they examined any housing that was perceived to be unaffordable and not just housing that was a severe cost burden (Pollack, Griffin and Lynch 2010). Housing cost burden may also have a greater impact on children than adults who might be able to weather effects better. Furthermore, the authors used self-reported height and weight to calculate BMI and not actual measures of height and weight.

The lack of association between severe housing cost burden and change in adiposity could be because enough time did not occur between the two measurements for a change to actually take place. Children are growing steadily at that age (Tanner 1990) and more time may be needed to see a change in adiposity. It is also likely that the sample size was not large enough to detect a statistically significant change since only 15% of the children in our sample lived in severe housing-cost burdened households.

We did not find child's diet to be associated with severe housing cost burden or to be a mediator of the relationship between severe housing cost burden and change in adiposity. It is possible that the supplemental foods and fruit and vegetable voucher WIC provides its participants might make it easier for severe housing cost burdened households to maintain a certain quality for their children's diet. Alternatively, it is possible that severe housing cost-burdened households are not spending less money on food. Although households living in unaffordable housing typically cut their food-related and medical-care related expenses (Harkness and Newman 2005, Joint Center for Housing Studies 2014), households may choose to cut other types of expenses such as utility bills, transportation, entertainment, and child care (Feeding America nd, Williams et al. 2004). Tabulations from the 2013 Consumer Expenditure Survey find that while the lowest income families spend the greatest percentage on housing (40%), they spend a smaller share on transportation (15%) and other expenses such as entertainment and alcohol (21%). Hence, the amount that goes toward food (16%) is not affected (Blumenberg 2015).

While the share of income going to food for the lowest income families is similar to higher income families, families in the lowest income quartile experiencing severe housing cost burden spend 17% of their income on food compared to 26% for their counterparts living in affordable housing (Joint Center for Housing Studies 2014). Hence, another reason could be that these low-income families do not have enough money to spend on food, whether it is unhealthy or not. On average, families in the U.S. in the lowest income quartile experiencing severe housing cost burden spend $208 on food a month compared to $343 for their counterparts living in affordable housing, and $298 for those in less severe forms of unaffordable housing (spending 30-50% of income on housing) (Joint Center for Housing Studies 2014). The small amount spent on food might explain why we found that children in our study living in the lowest income families were likely to experience a smaller increase in adiposity over time compared to their relatively higher income counterparts.

Although screen time was not found to be a mediator of the relationship between unaffordable housing and change in adiposity, we did find two or more hours of screen time a day to be associated with a decreased change in adiposity. It could be that screen time does not influence children's physical activity.

While mothers living in severe housing cost burdened households were at greater risk of depression, we did not find it to be a mediator of the relationship between severe housing cost burden and change in adiposity. This could be due to the small sample size or to additional factors buffering the effect of mother's depression. More than half of the children lived in households with 5 or more people. Some of these individuals may be adults who can act as caregivers for the child when the mother is depressed or they may provide the mother social support which can buffer feelings of stress and depression (Campos et al. 2014, Coburn et al.

2016, Cohen and Wills 1985). Additionally, the majority of the study population was Hispanic. Familism, where “close, supportive family relationships” are emphasized, tends to be higher among Hispanic families and it has been found to improve psychological health through increased social support (Campos et al. 2014).

In contrast, household size was observed to moderate the relationship between severe housing cost burden and childhood obesity, with larger households increasing the effect of severe housing cost burden on childhood obesity. When housing becomes unaffordable to low-income families, families are more likely to ‘double-up’ and this household crowding can add to the chaos and stress of the environment (Evans 2004, Leventhal and Newman 2010). The more people living in a household, the more likely it is to be chaotic (Evans 2004) and household chaos has been found to dysregulate the biological stress-response system in low-income young children (Lumeng et al. 2014). Furthermore, there is evidence to suggest that mothers living in crowded homes are not as responsive to their children (Evans et al. 2010).

Housing tenure was not found to be a moderator of the relationship between severe housing cost burden and childhood obesity. Home ownership has been found to moderate the relationship between unaffordable housing and health, possibly because home ownership is associated with greater wealth (Herbert, McCue and Sanchez-Moyano 2013, Pollack, Griffin and Lynch 2010). Our lack of findings could be because of the small percentage of families owning homes. Additionally, though a greater share of households experiencing severe housing cost burden lived with parents and relatives, these households may reap the previously-mentioned benefits from this situation that offset the chaos and stress of crowding such as informal child care and social support.

Contrary to other studies (Chaparro, Wang and Whaley 2013, Grow et al. 2010, Kimbro and Denney 2013), we did not find neighborhood median household income to be associated with obesity or with change in adiposity. While some families may choose to pay more for housing so that they can live in better neighborhoods that may buffer the detrimental effect of severe housing costs, Pollack et al. (2010) found that those who lived in unaffordable housing were more likely to live in worse neighborhoods. The lack of findings could be because of the lack of variation in this sample with many of the WIC families living in very similar neighborhoods.

In addition to being the first study, to our knowledge, to examine the effect of severe housing cost burden on obesity among preschool-aged children, this study has additional strengths. We used validated measured height and weight data (Crespi et al. 2012). The study examined often-hypothesized, but infrequently studied mechanisms by which a chronic financial stressor can increase the risk of childhood obesity, namely child's diet, sedentary behavior and mother's mental well-being (Gundersen et al. 2011). Additionally, the effect size of severe housing cost burden on childhood obesity among low-income children might be underestimated since the study sample consists of WIC families who receive nutrition education, supplemental foods and a fruit and vegetable voucher. These could buffer the negative impact of unaffordable housing on risk of childhood obesity.

This study has a few limitations related to measures. A perceived measure of unaffordable housing was used, however, it has not been validated. While the most extreme answer is considered to reflect severe housing cost burden it might instead reflect unaffordable housing. However, the measure may reflect burden more accurately since the extent of the burden is relative to a family's actual income (Pollack, Griffin and Lynch 2010). Even though the WIC population is low-income, spending half of a family's income on housing will have a greater impact on a very poor family compared to a family at 185% of the FPL. The question also does not define housing costs. It could encompass utility bills, property taxes, mortgage payments, etc. (Pollack, Griffin and Lynch 2010). Furthermore, the duration of severe housing cost burden is not known and duration of a stressor, whether it is acute or chronic, is important to determine the impact it has on parents and children. Is the experience of severe housing cost burden a one-time event and the family has the financial and/or social resources to get through the difficulty? Or is it a continuous experience and the family no longer has the financial or social resources from which to draw?

Child's diet and screen time are reported by the parents who might under-report the unhealthy behaviors and over-report the healthy ones. The validity of some of the diet measures might be an issue as a few had low to moderate Spearman's correlation coefficients and medium intra-class correlation coefficients (Koleilat and Whaley 2016). The screen time questions have not been validated. Issues with the validity of the mediators would attenuate the indirect effect (MacKinnon 2008). Neighborhood median household income is at the census tract level and census tract might not be an accurate representation of the family's neighborhood.

This study did not examine the other potential pathways by which unaffordable housing might increase the risk of childhood obesity, such as housing quality or sleep. Families living in unaffordable housing are more likely to live in poor quality homes that have toxins and pests (Bonnefoy 2007, Rauh, Landrigan and Claudio 2008). These can increase the likelihood that children develop asthma (Maheswaran et al. 2014, Rauh, Landrigan and Claudio 2008) and asthma is positively associated with childhood obesity (Beckett et al. 2001, Litonjua and Gold 2008). Children who live in a stressful environment tend to have poor sleep which can increase the risk of childhood obesity (Skelton et al. 2011).

While it is not possible to infer causality from the cross-sectional nature of the data, we ensured temporal precedence for the mediation analysis with change in adiposity by having the second measurement occur after the survey was conducted. Additionally, to examine the association of severe housing cost burden with obesity risk, obesity at a time point after the survey occurred was used. Although we controlled for potential confounders, it could be that a relationship between unaffordable housing and child obesity is due to a third variable such as genetics or another chronic stressor. Low-income families experience more chronic stressors than other families and it could be an unmeasured stressor that accounts for the relationship between unaffordable housing and childhood obesity.

This study focused on children aged 2-5 years. Findings may not be generalizable to children at other ages since there are critical periods in a child's growth and development which might make them more vulnerable to chronic stressors. Furthermore, unaffordable housing might not be a chronic stressor among older children. Stressors that induce feelings of instability might be more important in children while interpersonal and academic stressors might be more important in adolescence (Garasky et al. 2009, Monroe 2008).

Conclusion

Findings highlight the importance of considering unaffordable housing as a risk factor for childhood obesity and advance our understanding of the mechanisms by which financial chronic stress increases the risk of childhood obesity. While future research should explore the behavioral, biologic and neighborhood mechanisms by which unaffordable housing influences the risk of obesity, our findings have implications for obesity prevention programs and the importance of identifying children most in need. Given the severe shortage of affordable housing units for low-income families in the United States, increasing the availability of affordable housing units for low-income populations already struggling to make ends meet should be considered in the fight against childhood obesity.

CHAPTER 7: Conclusion

Results from these three chapters contribute to the literature on social determinants of health and childhood obesity and highlight the importance of both household- and neighborhood-level socioeconomic factors among low-income preschool-aged children.

While obesity rates among low-income preschool-aged children have improved since 2010-2011, increasing disparities suggest that the situation has worsened since the 2008-09 economic recession. With widening income inequality, a concern and given the differences in childhood obesity found among these children by household income, every effort should be made to ensure that low-income families enroll in all applicable safety net programs for which they are qualified since even relatively little differences in income were found to protect against obesity risk. Additionally, every effort should be made to increase parents' educational attainment given the striking differences in childhood obesity by household education.

In identifying children at increased risk for obesity, the financial strain of unaffordable housing should be considered. Since affordable housing is difficult to come by for many struggling families in the United States (Joint Center for Housing Studies 2015), innovative programs and efforts to make housing more affordable for low-income populations should be explored. Future research should explore the mechanisms by which unaffordable housing increases early childhood obesity risk as well as the factors responsible for the widening disparities in obesity.

APPENDICES

APPENDIX FOR CHAPTER 4

Table A.1. Sample sizes by year and age

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
2 years	69,070	65,849	64,145	62,685	62,353	66,893	77,685	53,695	50,842	58,273	61,092	57,322
3 years	66,500	62,907	61,637	59,044	59,127	61,769	71,465	51,197	50,452	58,177	57,629	57,679
4 years	50,947	51,355	50,154	47,256	47,069	49,146	57,708	40,284	40,544	47,802	47,670	45,345

Table A.2. Sample sizes by household income for each year and age, 2003-2014

	2003 N (%)	2004 N (%)	2005 N (%)	2006 N (%)	2007 N (%)	2008 N (%)	2009 N (%)	2010 N (%)	2011 N (%)	2012 N (%)	2013 N (%)	2014 N (%)
2 years	69,070	65,849	64,145	62,685	62,353	66,893	77,685	53,695	50,842	58,273	61,092	57,322
≤ 50% FPL	17,648 (25.6)	14,990 (22.8)	14,329 (22.3)	13,301 (21.2)	13,116 (21.0)	14,939 (22.3)	20,981 (27.0)	16,217 (30.2)	16,250 (32.0)	18,677 (32.1)	20,283 (33.2)	18,284 (31.9)
50.1 – 100.0% FPL	29,875 (43.3)	29,961 (45.5)	29,557 (46.1)	29,289 (46.7)	29,319 (47.0)	30,994 (46.3)	35,855 (46.2)	24,693 (46.0)	22,865 (45.0)	25,920 (44.5)	26,791 (43.9)	25,258 (44.1)
100.1 – 133.0% FPL	11,992 (17.4)	11,765 (17.9)	11,474 (17.9)	11,487 (18.3)	11,309 (18.1)	11,872 (17.8)	12,043 (15.5)	7,348 (13.7)	6,672 (13.1)	7,947 (13.6)	8,216 (13.5)	8,146 (14.2)
133.1 – 185.0% FPL	9,555 (13.8)	9,133 (13.9)	8,785 (13.7)	8,608 (13.7)	8,609 (13.8)	9,088 (13.6)	8,806 (11.3)	5,437 (10.1)	5,055 (9.9)	5,729 (9.8)	5,802 (9.5)	5,634 (9.8)
3 years	66,500	62,907	61,637	59,044	59,127	61,769	71,465	51,197	50,452	58,177	57,629	57,679
≤ 50% FPL	17,012 (25.6)	14,596 (23.2)	13,749 (22.3)	12,311 (20.9)	12,382 (20.9)	13,533 (21.9)	18,752 (26.2)	14,740 (28.8)	15,370 (30.5)	18,349 (31.5)	18,385 (31.9)	18,022 (31.3)
50.1 – 100.0% FPL	28,853 (43.4)	28,694 (45.6)	28,404 (46.1)	27,657 (46.8)	28,075 (47.5)	28,929 (46.8)	33,444 (46.8)	24,008 (46.9)	23,400 (46.4)	26,742 (46.0)	26,158 (45.4)	26,039 (45.1)
100.1 – 133.0% FPL	11,552 (17.4)	11,094 (17.6)	10,910 (17.7)	10,748 (18.2)	10,725 (18.1)	10,966 (17.8)	11,252 (15.7)	7,203 (14.1)	6,626 (13.1)	7,591 (13.1)	7,717 (13.4)	8,143 (14.1)
133.1 – 185.0% FPL	9,083 (13.7)	8,523 (13.6)	8,574 (13.9)	8,328 (14.1)	7,945 (13.4)	8,341 (13.5)	8,017 (11.2)	5,246 (10.3)	5,056 (10.0)	5,495 (9.5)	5,369 (9.3)	5,475 (9.5)
4 years	50,947	51,355	50,154	47,256	47,069	49,146	57,708	40,284	40,544	47,802	47,670	45,345
≤ 50% FPL	13,057 (25.6)	11,923 (23.3)	11,226 (22.4)	9,910 (21.0)	9,621 (20.4)	10,689 (21.8)	14,822 (25.7)	11,529 (28.6)	12,194 (30.1)	14,393 (30.1)	14,785 (31.0)	13,795 (30.4)
50.1 – 100.0% FPL	22,300 (43.8)	23,376 (45.5)	23,243 (46.3)	22,496 (47.6)	22,406 (47.6)	23,229 (47.3)	27,414 (47.5)	19,296 (47.9)	19,042 (47.0)	22,489 (47.1)	22,552 (47.3)	21,056 (46.4)
100.1 – 133.0% FPL	8,752 (17.2)	9,029 (17.6)	8,977 (17.9)	8,446 (17.9)	8,645 (18.4)	8,744 (17.8)	9,107 (15.8)	5,593 (13.9)	5,329 (13.1)	6,294 (13.2)	6,251 (13.1)	6,307 (13.9)
133.1 – 185.0% FPL	6,838 (13.4)	7,002 (13.6)	6,708 (13.4)	6,404 (13.6)	6,397 (13.6)	6,484 (13.2)	6,365 (11.0)	3,866 (9.6)	3,979 (9.8)	4,626 (9.7)	4,082 (8.6)	4,187 (9.2)

FPL=Federal Poverty Level

Table A.3. Sample sizes by household education for each year and age, 2003-2014

	2003 N (%)	2004 N (%)	2005 N (%)	2006 N (%)	2007 N (%)	2008 N (%)	2009 N (%)	2010 N (%)	2011 N (%)	2012 N (%)	2013 N (%)	2014 N (%)
2 years	69,070	65,849	64,145	62,685	62,353	66,893	77,685	53,695	50,842	58,273	61,092	57,322
< high school	41,744 (60.4)	39,409 (59.9)	37,766 (58.9)	36,512 (58.3)	36,072 (57.9)	38,249 (57.2)	42,763 (55.1)	28,180 (52.5)	26,021 (51.2)	28,449 (48.8)	28,572 (46.8)	26,381 (46.0)
High school	20,024 (29.0)	19,461 (29.6)	19,371 (30.2)	19,216 (30.7)	19,430 (31.2)	20,996 (31.4)	25,462 (32.8)	18,608 (34.7)	17,891 (35.2)	21,255 (36.5)	22,766 (37.3)	21,421 (37.4)
Some college	5,684 (8.2)	5,367 (8.2)	5,300 (8.3)	5,291 (8.4)	5,189 (8.3)	5,822 (8.7)	7,269 (9.4)	5,287 (9.9)	5,191 (10.2)	6,164 (10.6)	6,960 (11.4)	6,686 (11.7)
College or more	1,618 (2.3)	1,612 (2.5)	1,708 (2.7)	1,666 (2.7)	1,662 (2.7)	1,826 (2.7)	2,191 (2.8)	1,620 (3.0)	1,739 (3.4)	2,405 (4.1)	2,794 (4.6)	2,834 (4.9)
3 years	66,500	62,907	61,637	59,044	59,127	61,769	71,465	51,197	50,452	58,177	57,629	57,679
< high school	41,171 (61.9)	38,515 (61.2)	37,208 (60.4)	35,145 (59.5)	34,802 (58.9)	35,597 (57.6)	40,101 (56.1)	27,823 (54.3)	26,306 (52.1)	29,685 (51.0)	27,907 (48.4)	27,281 (47.3)
High school	18,705 (28.1)	18,100 (28.8)	18,123 (29.4)	17,660 (29.9)	17,997 (30.4)	19,392 (31.4)	23,139 (32.4)	17,072 (33.4)	17,525 (34.7)	20,598 (35.4)	21,148 (36.7)	21,387 (37.1)
Some college	5,171 (7.8)	4,947 (7.9)	4,851 (7.9)	4,757 (8.1)	4,850 (8.2)	5,187 (8.4)	6,242 (8.7)	4,808 (9.4)	4,981 (9.9)	5,714 (9.8)	6,137 (10.7)	6,373 (11.1)
College or more	1,453 (2.2)	1,345 (2.2)	1,455 (2.4)	1,482 (2.5)	1,478 (2.5)	1,593 (2.6)	1,983 (2.8)	1,494 (2.9)	1,640 (3.3)	2,180 (3.8)	2,437 (4.2)	2,638 (4.6)
4 years	50,947	51,355	50,154	47,256	47,069	49,146	57,708	40,284	40,544	47,802	47,670	45,345
< high school	31,810 (62.4)	31,798 (61.9)	31,091 (62.0)	28,632 (60.6)	28,407 (60.4)	28,898 (58.8)	32,961 (57.1)	22,519 (55.9)	21,732 (53.6)	24,905 (52.1)	24,603 (51.6)	22,461 (49.5)
High school	14,207 (27.9)	14,432 (28.1)	14,207 (28.3)	13,952 (29.5)	13,840 (29.4)	15,037 (30.6)	18,302 (31.7)	13,101 (32.5)	13,644 (33.7)	16,460 (34.4)	16,570 (34.8)	16362 (36.1)
Some college	3,906 (7.7)	4,042 (7.9)	3,788 (7.6)	3,588 (7.6)	3,673 (7.8)	4,025 (8.2)	4,899 (8.5)	3,544 (8.8)	3,899 (9.6)	4,601 (9.6)	4,649 (9.8)	4,623 (10.2)
College or more	1,024 (2.0)	1,083 (2.1)	1,068 (2.1)	1,084 (2.3)	1,149 (2.4)	1,186 (2.4)	1,546 (2.7)	1,120 (2.8)	1,269 (3.1)	1,836 (3.8)	1,848 (3.9)	1,899 (4.2)

Table A.4. Sample sizes by neighborhood median income for each year and age, 2003-2014

	2003 N (%)	2004 N (%)	2005 N (%)	2006 N (%)	2007 N (%)	2008 N (%)	2009 N (%)	2010 N (%)	2011 N (%)	2012 N (%)	2013 N (%)	2014 N (%)
2 years	69,070	65,849	64,145	62,685	62,353	66,893	77,685	53,695	50,842	58,273	61,092	57,322
≤ $ 32,738	17,173 (24.9)	16,368 (24.9)	16,037 (25.0)	15,369 (24.5)	15,233 (24.4)	16,309 (24.4)	18,625 (24.0)	14,144 (26.3)	13,614 (26.8)	14,862 (25.5)	15,162 (24.8)	14,236 (24.8)
$32,739 - 40,278	18,358 (26.6)	17,238 (26.2)	16,600 (25.9)	16,221 (25.9)	15,917 (25.5)	16,935 (25.3)	19,720 (25.4)	12,479 (23.2)	11,768 (23.2)	13,533 (23.2)	14,117 (23.1)	13,222 (23.1)
$40,279 - 51,534	17,408 (25.2)	16,638 (25.3)	16,260 (25.4)	15,902 (25.4)	15,861 (25.4)	16,847 (25.2)	19,612 (25.3)	12,916 (24.1)	12,097 (23.8)	14,057 (24.1)	15,228 (24.9)	14,288 (24.9)
≥ $51,535	16,131 (23.4)	15,605 (23.7)	15,248 (23.8)	15,193 (24.2)	15,342 (24.6)	16,802 (25.1)	19,728 (25.4)	14,156 (26.4)	13,363 (26.3)	15,821 (27.2)	16,585 (27.2)	15,576 (27.2)
3 years	66,500	62,907	61,637	59,044	59,127	61,769	71,465	51,197	50,452	58,177	57,629	57,679
≤ $ 32,738	16,774 (25.2)	15,765 (25.1)	15,533 (25.2)	14,565 (24.7)	14,356 (24.3)	15,088 (24.4)	17,357 (24.3)	13,669 (26.7)	13,375 (26.5)	14,981 (25.8)	14,641 (25.4)	14,323 (24.8)
$32,739 - 40,278	17,464 (26.3)	16,607 (26.4)	16,203 (26.3)	15,304 (25.9)	15,302 (25.9)	15,886 (25.7)	18,039 (25.2)	11,945 (23.3)	11,876 (23.5)	13,601 (23.4)	13,554 (23.5)	13,570 (23.5)
$40,279 - 51,534	16,922 (25.5)	15,796 (25.1)	15,476 (25.1)	15,118 (25.6)	14,979 (25.3)	15,739 (25.5)	17,970 (25.2)	12,302 (24.0)	12,170 (24.1)	14,252 (24.5)	14,104 (24.5)	14,425 (25.0)
≥ $51,535	15,340 (23.1)	14,739 (23.4)	14,425 (23.4)	14,057 (23.8)	14,490 (24.5)	15,056 (24.4)	18,099 (25.3)	13,281 (25.9)	13,031 (25.8)	15,343 (26.4)	15,330 (26.6)	15,361 (26.6)
4 years	50,947	51,355	50,154	47,256	47,069	49,146	57,708	40,284	40,544	47,802	47,670	45,345
≤ $ 32,738	12,697 (24.9)	12,867 (25.1)	12,492 (24.9)	11,722 (24.8)	11,519 (24.5)	12,010 (24.4)	13,950 (24.2)	10,612 (26.3)	10,870 (26.8)	12,147 (25.4)	12,154 (25.5)	11,632 (25.7)
$32,739 - 40,278	13,536 (26.6)	13,557 (26.4)	13,211 (26.3)	12,288 (26.0)	12,073 (25.7)	12,610 (25.7)	14,801 (25.7)	9,495 (23.6)	9,590 (23.7)	11,299 (23.6)	11,386 (23.9)	10,667 (23.5)
$40,279 - 51,534	13,068 (25.7)	13,205 (25.7)	12,712 (25.4)	12,038 (25.5)	12,000 (25.5)	12,525 (25.5)	14,631 (25.4)	9,728 (24.2)	9,710 (24.0)	11,875 (24.8)	11,877 (24.9)	11,240 (24.8)
≥ $51,535	11,646 (22.9)	11,726 (22.8)	11,739 (23.4)	11,208 (23.7)	11,477 (24.4)	12,001 (24.4)	14,326 (24.8)	10,449 (25.9)	10,374 (25.6)	12,481 (26.1)	12,253 (25.7)	11,806 (26.0)

Table A.5. Sample sizes by neighborhood unaffordable housing for each year and age, 2003-2014

	2003 N (%)	2004 N (%)	2005 N (%)	2006 N (%)	2007 N (%)	2008 N (%)	2009 N (%)	2010 N (%)	2011 N (%)	2012 N (%)	2013 N (%)	2014 N (%)
2 years	69,070	65,849	64,145	62,685	62,353	66,893	77,685	53,695	50,842	58,273	61,092	57,322
≤ 40.0%	2,925 (4.2)	2,530 (3.8)	2,631 (4.1)	2,601 (4.2)	2,618 (4.2)	2,869 (4.3)	3,384 (4.4)	2,339 (4.4)	2,270 (4.5)	2,641 (4.5)	2,871 (4.7)	2,620 (4.6)
40.1-55.0%	28,331 (41.0)	27,162 (41.3)	26,389 (41.1)	26,081 (41.6)	25,560 (41.0)	27,400 (41.0)	32,204 (41.5)	18,325 (34.1)	17,378 (34.2)	20,052 (34.4)	21,124 (34.6)	20,047 (35.0)
55.1-70.0%	34,406 (49.8)	32,773 (49.8)	31,856 (49.7)	30,825 (49.2)	30,869 (49.5)	33,058 (49.4)	38,046 (49.0)	27,377 (51.0)	25,880 (50.9)	29,334 (50.3)	30,630 (50.1)	28,527 (49.8)
≥70.1%	3,408 (4.9)	3,384 (5.1)	3,269 (5.1)	3,178 (5.1)	3,306 (5.3)	3,566 (5.3)	4,051 (5.2)	5,654 (10.5)	5,314 (10.5)	6,246 (10.7)	6,467 (10.6)	6,128 (10.7)
3 years	66,500	62,907	61,637	59,044	59,127	61,769	71,465	51,197	50,452	58,177	57,629	57,679
≤ 40.0%	2,578 (3.9)	2,573 (4.1)	2,377 (3.9)	2,406 (4.1)	2,456 (4.2)	2,588 (4.2)	3,063 (4.3)	2,172 (4.2)	2,153 (4.3)	2,504 (4.3)	2,634 (4.6)	2,625 (4.6)
40.1-55.0%	27,358 (41.1)	25,848 (41.1)	25,455 (41.3)	24,398 (41.3)	24,365 (41.2)	25,216 (40.8)	29,571 (41.4)	17,388 (34.0)	17,174 (34.0)	19,803 (34.0)	19,678 (34.2)	19,755 (34.3)
55.1-70.0%	33,187 (49.9)	31,271 (49.7)	30,530 (49.5)	29,263 (49.6)	29,189 (49.4)	30,692 (49.7)	35,066 (49.1)	26,133 (51.0)	25,814 (51.2)	29,648 (51.0)	29,070 (50.4)	29,121 (50.5)
≥70.1%	3,377 (5.1)	3,215 (5.1)	3,275 (5.3)	2,977 (5.0)	3,117 (5.3)	3,273 (5.3)	3,765 (5.3)	5,504 (10.8)	5,311 (10.5)	6,222 (10.7)	6,247 (10.8)	6,178 (10.7)
4 years	50,947	51,355	50,154	47,256	47,069	49,146	57,708	40,284	40,544	47,802	47,670	45,345
≤ 40.0%	2,038 (4.0)	2,020 (3.9)	2,012 (4.0)	1,795 (3.8)	1,952 (4.2)	2,030 (4.1)	2,481 (4.3)	1,667 (4.1)	1,688 (4.2)	2,050 (4.3)	1,988 (4.2)	2,022 (4.5)
40.1-55.0%	20,992 (41.2)	21,031 (41.0)	20,550 (41.0)	19,652 (41.6)	19,218 (40.8)	20,279 (41.3)	23,866 (41.4)	13,587 (33.7)	13,755 (33.9)	16,233 (34.0)	16,197 (34.0)	15,327 (33.8)
55.1-70.0%	25,302 (49.7)	25,698 (50.0)	25,058 (50.0)	23,290 (49.3)	23,479 (49.9)	24,179 (49.2)	28,372 (49.2)	20,822 (51.7)	20,840 (51.4)	24,435 (51.1)	24,428 (51.2)	23,088 (50.9)
≥70.1%	2,615 (5.1)	2,606 (5.1)	2,534 (5.1)	2,519 (5.3)	2,420 (5.1)	2,658 (5.4)	2,989 (5.2)	4,208 (10.5)	4,261 (10.5)	5,084 (10.6)	5,057 (10.6)	4,908 (10.8)

APPENDIX FOR CHAPTER 5

Table B1. Multiple logistic regression analyses for obesity and household education for WIC children in Los Angeles County[†] across all three age groups

	2-year-old children N=605,326		**3-year-old children** N=584,349		**4-year-old children** N=468,426	
	Model 1 b(SE)	Model 2 b(SE)	Model 1 b(SE)	Model 2 b(SE)	Model 1 b(SE)	Model 2 b(SE)
Education (College or more, Ref)						
Less than high school	0.318 (0.024) *** [c]	0.263 (0.036)***[c]	0.225(0.023)***[c]	0.173 (0.035)***[c]	0.178 (0.025)***[c]	0.103 (0.038)**[c]
High school	0.277 (0.024) ***	0.233 (0.037)***	0.171(0.023)***	0.123 (0.036)***	0.124 (0.025)***	0.055 (0.039)
Some college	0.192 (0.026) ***	0.166 (0.040)***	0.135 (0.025)***	0.126 (0.038)**	0.089 (0.027)**	0.021 (0.042)
2010-14 time period (2003-07, Ref)	0.068 (0.007) ***	-0.013 (0.046)	0.056 (0.007)***	-0.020 (0.044)	0.026 (0.007)***	-0.093 (0.048)
Education x 2010-14 time period (College or more in 2003-07, Ref)						
Less than high school, 2010-14		0.095 (0.047)*[a]		0.088 (0.045) [b]		0.125 (0.049) *
High school, 2010-14		0.074 (0.048)		0.079 (0.046)		0.115 (0.050) *
Some college, 2010-14		0.039 (0.052)		0.009 (0.050)		0.113 (0.023) *

[†]All models adjusted for child's gender and caregiver's race/ethnicity
FPL = Federal poverty level; Ref=reference group.
t-statistic significant at * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Wald chi-square significant at [a] $p < 0.05$; [b] $p < 0.01$; [c] < 0.001

Table B2. Multiple logistic regression analyses for obesity and neighborhood unaffordable housing for WIC children in Los Angeles County† across all three age groups

	2-year-old children N=605,326		3-year-old children N=584,349		4-year-old children N=468,426	
	Model 1 b(SE)	Model 2 b(SE)	Model 1 b (SE)	Model 2 b (SE)	Model 1 b(SE)	Model 2 b(SE)
Neighborhood unaffordable housing[o] (≤ 40.0%, Ref)						
≥ 70.1%	0.146 (0.022)*** [c]	0.134 (0.033)*** [c]	0.140 (0.021)*** [c]	0.133 (0.032)*** [c]	0.140 (0.023)*** [c]	0.105 (0.034)** [c]
55.1-70.0%	0.116 (0.018)***	0.123 (0.026)***	0.114 (0.018)***	0.114 (0.025)***	0.113 (0.020)***	0.108 (0.027)***
40.1-55.0%	0.067 (0.019)***	0.087 (0.026)***	0.056 (0.018)**	0.066 (0.025)**	0.065 (0.020)**	0.068 (0.028) *
2010-14 time period (2003-07, Ref)	0.053 (0.007)***	0.076 (0.035) *	0.042 (0.007)***	0.050 (0.034)	0.013 (0.007)	0.008 (0.038)
Neighborhood unaffordable housing x 2010-14 time period (≤ 40.0% in 2003-07, Ref)						
40.1-55.0%, 2010-14		-0.044 (0.037)		-0.021 (0.036)		-0.009 (0.039)
55.1-70.0%, 2010-14		-0.014 (0.037)		-0.001 (0.036)		-0.009 (0.039)
≥ 70.1%, 2010-14		0.013 (0.044)		0.010 (0.042)		0.055 (0.046)

†All models adjusted for child's gender and caregiver's race/ethnicity
[o]percent of residents spending > 30% of their household income on housing costs
FPL = Federal poverty level; Ref=reference group.
t-statistic significant at * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Wald chi-square significant at [a] $p < 0.05$; [b] $p < 0.01$; [c] < 0.001

APPENDIX FOR CHAPTER 6

Table C1. Variables and how they were defined for analytical purposes

Variable	Operational definition/how expressed
Dependent Variables	
Obesity status	• Binary
Change in BMIz	• Change in body mass index z-score (BMIz) (continuous)
Change in WHZ	• Change in weight-for-height z-score (WHZ) (continuous)
Main Independent Variable	
Severe housing cost burden	• Perceived difficulty in paying for housing (binary)
Mediators	
Fruit and vegetable consumption	• Number of servings of fruits & vegetables on an average day (continuous)
Unhealthy food score	• Score based on consuming fast food ≥ 1 week, SSB ≥ 1 day, and sweetened foods ≥ 1 day
Screen time	• Total hours of TV and video and computer games a day (continuous)
Mother's depression	• Patient Health Questionnaire-2 (PHQ-2) 2-item depression screener (continuous) • Binary measure
Covariates	
Child's age	• Months (continuous)
Child's gender	• Girl/boy (binary)
Child's race/ethnicity	• NH White, NH Black, Hispanic, Asian (categorical)
Child's baseline BMIz/WHZ	• Calculated from annual height and weight measurements, derived from CDC's gender- and age-specific growth reference values (continuous)
Mother's BMI	• Calculated from mother's reported height and weight (continuous)
Mother's education	• Highest grade completed of mother [<high school, high school, some college, college or more] (categorical)
Household income	• Household income as %FPL (continuous)
Neighborhood median household income	• 5-year estimate of median household income of the child's census tract (continuous)
Year of survey	• 2011/2014 (binary)
Potential confounders and moderators	
Food insecurity	• USDA's 6-item food insecurity measure [high/marginal, low, and very low food security] (categorical)
Housing tenure	• Respondent housing status [in a home owned by parents or relatives, in an apartment or home owned by respondent, in an apartment or home rented by respondent, other] (categorical)
Household size	• Number of people living in household (continuous)

FPL= Federal Poverty Level

Table C2. Questions in the WIC Survey of relevant variables

	Question	Response categories or units
DIET		
Fast food frequency	How often does NAME eat any food including meals and snacks from a fast food restaurant, like McDonald's, Taco Bell, Burger King, Kentucky Fried Chicken, or another similar place?	1= 4+ times/wk 2 = 1-3 times/wk 3 = Less than once a week but at least once a month 4 = Less than once a month 5= Never
# of fruit servings per day	On an average day, about how many servings of fruits does NAME eat?	Number fruits per day
# of vegetable servings per day	On an average day, about how many servings of vegetables does NAME eat?	Number vegetables per day
100% fruit juice intake	On an average day, how many times does NAME drink 100% fruit juice?	Number times per day
Sweetened milk	On an average day, how many times does NAME drink chocolate milk or sweetened milk?	Number times per day
Non-100% juice intake	On an average day, how many other fruit juice drinks that are not 100% juice, such as Sunny Delight, Capri Sun, or lemonade does NAME drink?	Number drinks per day 98= Some but less than 1 full serving
Sweetened drink intake	On an average day, about how many sweetened drinks such as Gatorade, Kool aid, or Red Bull does NAME drink?	Number drinks per day 98= Some but less than 1 full serving
Diet soda intake	On an average day, about how many diet sodas such as Diet Coke or Diet Mountain Dew, does NAME drink?	Number drinks per day 98= Some but less than 1 full serving
Soda intake	On an average day, about how many regular sodas such as Coke or Mountain Dew, does NAME drink? Do not include diet sodas or sugar-free drinks.	Number drinks per day 98= Some but less than 1 full serving
Sweets/sweetened food intake	On an average day, how many times does NAME eat sweets or sweetened foods, such as sweetened cereals, fruit bars, pop tarts, donuts, cookies and candies?	Number sweets per day

	Question	Response categories or units
	Mother's depressive symptoms	
No pleasure	Think about the past two weeks, how often have you been bothered by having little interest or pleasure in doing things?	1= Not at all 2 = Several days 3 = More than half the days 4 = Nearly everyday
Depressed	Think about the past two weeks, how often have you been bothered by feeling down, depressed or hopeless?	1= Not at all 2 = Several days 3 = More than half the days 4 = Nearly everyday
	Food insecurity	
Food didn't last	"The food that we bought just didn't last, and we didn't have money to get more." Was that often, sometimes or never true for your household in the last 12 months?	1= Often 2 = Sometimes 3 = Never
Balanced meals	"We couldn't afford to eat balanced meals." Was that often, sometimes or never true for your household in the last 12 months?	1= Often 2 = Sometimes 3 = Never
Cut meals	In the last 12 months, that is since last (April/May/June), did you or other adults in your household ever cut the size of your meals or skip meals because there wasn't enough money for food?	1= Yes 2 = No
Frequency cut meals	If yes: How often did this happen – almost every month, some months but not every month or in only 1 or 2 months?	1= Almost every month 2 = Some months, not every 3 = Only 1 or 2 months
Not enough money	In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?	1= Yes 2 = No
Hungry	In the last 12 months, were you ever hungry but didn't eat because there wasn't enough money for food?	1= Yes 2 = No
	Sedentary Behavior	
TV in a day	On an average day, how many hours does NAME watch television? Only include time when (he) (she) is sitting and watching TV. Just your best estimate.	Number of hours 0= less than 1 hour
Video/computer games	On an average day, how many hours does NAME play video or computer games? Just your best estimate.	Number of hours 0= less than 1 hour

	Questions	Response categories or units
Housing		
Housing tenure	Which of the following best describes where you currently live – in a home owned by your parents or relatives, in an apartment or home that you own, or in an apartment or home that you rent?	1 = Parents/relative's home 2 = Home they own 3 = Renter 4 = Other
Finding housing	How easy or difficult is it for you to find housing – very difficult, somewhat difficult, somewhat easy or very easy?	1 = Very difficult 2 = Somewhat difficult 3 = Somewhat easy 4 = Very easy
Paying for housing	How easy or difficult is it for you to pay for housing – very difficult, somewhat difficult, somewhat easy or very easy?	1 = Very difficult 2 = Somewhat difficult 3 = Somewhat easy 4 = Very easy 5 = Not applicable (don't pay)
Residential mobility	In the past three years, how many different places have you lived, including your current residence?	Number of different places
Household size	Including yourself, how many people currently live in your household?	Number of people

REFERENCES

AAP Committee on Public Education. 2001. "Children, Adolescents, and Television." *Pediatrics* 107(2):423-26. doi: 10.1542/peds.107.2.423.

Adam, T. C. and E. S. Epel. 2007. "Stress, Eating and the Reward System." *Physiol Behav* 91(4):449-58. doi: 10.1016/j.physbeh.2007.04.011.

Adams, Kimberly, Roger G Sargent, Sharon H Thompson, Donna Richter, Sara J. Corwin and Thomas J. Rogan. 2000. "A Study of Body Weight Concerns and Weight Control Practices of 4th and 7th Grade Adolescents." *Ethnicity and Health* 5(1):79-94.

Adler, N. E. and J. Stewart. 2010a. "Preface to the Biology of Disadvantage: Socioeconomic Status and Health." *Ann N Y Acad Sci* 1186:1-4. doi: 10.1111/j.1749-6632.2009.05385.x.

Adler, Nancy E. and Katherine Newman. 2002. "Socioeconomic Disparities in Health: Pathways and Policies." *Health affairs* 21(2):60-76. doi: 10.1377/hlthaff.21.2.60.

Adler, Nancy E. and Judith Stewart. 2010b. "Health Disparities across the Lifespan: Meaning, Methods, and Mechanisms." *Annals of the New York Academy of Sciences* 1186(1):5-23. doi: 10.1111/j.1749-6632.2009.05337.x.

Agras, W. Stewart, Lawrence D. Hammer, Fiona McNicholas and Helena C. Kraemer. 2004. "Risk Factors for Childhood Overweight: A Prospective Study from Birth to 9.5 Years." *J Pediatr* 145(1):20-25. doi: http://dx.doi.org/10.1016/j.jpeds.2004.03.023.

Anderson, S. E. and R. C. Whitaker. 2009. "Prevalence of Obesity among Us Preschool Children in Different Racial and Ethnic Groups." *Arch Pediatr Adolesc Med* 163(4):344-8. doi: 10.1001/archpediatrics.2009.18.

Anderson, S. E. and R. C. Whitaker. 2011. "Attachment Security and Obesity in Us Preschool-Aged Children." *Arch Pediatr Adolesc Med* 165(3):235-42. doi: 10.1001/archpediatrics.2010.292.

Anderson, S. E., R. A. Gooze, S. Lemeshow and R. C. Whitaker. 2012. "Quality of Early Maternal-Child Relationship and Risk of Adolescent Obesity." *Pediatrics* 129(1):132-40. doi: 10.1542/peds.2011-0972.

Andreyeva, T., J. Luedicke, A. E. Middleton, M. W. Long and M. B. Schwartz. 2012. "Positive Influence of the Revised Special Supplemental Nutrition Program for Women, Infants, and Children Food Packages on Access to Healthy Foods." *J Acad Nutr Diet* 112(6):850-8. doi: 10.1016/j.jand.2012.02.019.

Andreyeva, Tatiana, Joerg Luedicke, Kathryn E. Henderson and Marlene B. Schwartz. 2014. "The Positive Effects of the Revised Milk and Cheese Allowances in the Special Supplemental Nutrition Program for Women, Infants, and Children." *J Acad Nutr Diet* 114(4):622-30. doi: http://dx.doi.org/10.1016/j.jand.2013.08.018.

Aneshensel, C.S. 2013. *Theory-Based Data Analysis for the Social Sciences. 2nd Ed*. Thousand Oaks, Ca.: Sage Publications, Inc.

Babey, S. H., T. A. Hastert, J. Wolstein and A. L. Diamant. 2010. "Income Disparities in Obesity Trends among California Adolescents." *Am J Public Health* 100(11):2149-55. doi: 10.2105/ajph.2010.192641.

Bagner, D. M., J. W. Pettit, P. M. Lewinsohn, J. R. Seeley and J. Jaccard. 2013. "Disentangling the Temporal Relationship between Parental Depressive Symptoms and Early Child Behavior Problems: A Transactional Framework." *J Clin Child Adolesc Psychol* 42(1):78-90. doi: 10.1080/15374416.2012.715368.

Baker, B. L., L. L. McIntyre, J. Blacher, K. Crnic, C. Edelbrock and C. Low. 2003. "Pre-School Children with and without Developmental Delay: Behaviour Problems and Parenting Stress over Time." *Journal of Intellectual Disability Research* 47(4-5):217-30. doi: 10.1046/j.1365-2788.2003.00484.x.

Bakermans-Kranenburg, M. J. and M. H. van Ijzendoorn. 2006. "Gene-Environment Interaction of the Dopamine D4 Receptor (Drd4) and Observed Maternal Insensitivity Predicting

Externalizing Behavior in Preschoolers." *Dev Psychobiol* 48(5):406-9. doi: 10.1002/dev.20152.

Barlow, Sarah E. 2007. "Expert Committee Recommendations Regarding the Prevention, Assessment, and Treatment of Child and Adolescent Overweight and Obesity: Summary Report." *Pediatrics* 120(Supplement 4):S164-S92. doi: 10.1542/peds.2007-2329C.

Barroso, C. S., A. Roncancio, M. B. Hinojosa and E. Reifsnider. 2012. "The Association between Early Childhood Overweight and Maternal Factors." *Child Obes* 8(5):449-54. doi: 10.1089/chi.2011.0094.

Baum, A., L. Cohen and M. Hall. 1993. "Control and Intrusive Memories as Possible Determinants of Chronic Stress." *Psychosom Med* 55:274-86.

Baum, A., J. P. Garofalo and A. M. Yali. 1999. "Socioeconomic Status and Chronic Stress. Does Stress Account for Ses Effects on Health?". *Ann N Y Acad Sci* 896:131-44.

Baum, Charles L and Christopher J Ruhm. 2009. "Age, Socioeconomic Status and Obesity Growth." *Journal of health economics* 28(3):635-48.

Beckett, William S, David R Jacobs Jr, Xinhua Yu, Carlos Iribarren and O Dale Williams. 2001. "Asthma Is Associated with Weight Gain in Females but Not Males, Independent of Physical Activity." *American Journal of Respiratory and Critical Care Medicine* 164(11):2045-50.

Berrington de Gonzalez, A., P. Hartge, J. R. Cerhan, A. J. Flint, L. Hannan, R. J. MacInnis and Et al. 2010. "Body-Mass Index and Mortality among 1.46 Million White Adults." *N Engl J Med* 363(23):2211-9. doi: 10.1056/NEJMoa1000367.

Bjorntorp, P. 2001. "Do Stress Reactions Cause Abdominal Obesity and Comorbidities?". *Obes Rev* 2(2):73-86.

Block, Jason P, Richard A Scribner and Karen B DeSalvo. 2004. "Fast Food, Race/Ethnicity, and Income: A Geographic Analysis." *Am J Prev Med* 27(3):211-17.

Blumenberg, E. 2015. “Tabulations of 2013 Consumer Expenditure Survey: Household Expenditures by Household Income Level.”

Bohn, S. and E. Schiff. 2011. "The Great Recession and Distribution of Income in California." Vol.: Public Policy Institute of California,.

Bohn, S. and C. Danielson. 2016. "Income Inequality and the Safety Net in California." Vol.: Public Policy Institute of California,.

Bohn S., Danielson C. and M. Bandy. 2015. "Child Poverty in California." Vol.: Public Policy Institute of California,.

Bonnefoy, Xavier. 2007. "Inadequate Housing and Health: An Overview." *International Journal of Environment and Pollution* 30(3):411-29.

Borghans, Lex and Bart Golsteyn. 2005. "Time Discounting and the Body Mass Index."

Bose, M., B. Olivan and B. Laferrere. 2009. "Stress and Obesity: The Role of the Hypothalamic-Pituitary-Adrenal Axis in Metabolic Disease." *Curr Opin Endocrinol Diabetes Obes* 16(5):340-6. doi: 10.1097/MED.0b013e32832fa137.

Braveman, P. 2006. "Health Disparities and Health Equity: Concepts and Measurement." *Annu Rev Public Health* 27:167-94. doi: 10.1146/annurev.publhealth.27.021405.102103.

Braveman, P., S. Egerter and C. Barclay. 2011. "Issue Brief 4: Income, Wealth, and Health." Vol. *Exploring the Social Determinants of Health.* New Jersey: Robert Wood Johnson Foundation.

Braveman, P. A., C. Cubbin, S. Egerter, S. Chideya, K. S. Marchi, M. Metzler and S. Posner. 2005. "Socioeconomic Status in Health Research: One Size Does Not Fit All." *Jama* 294(22):2879-88. doi: 10.1001/jama.294.22.2879.

Braveman, P. A., S. Kumanyika, J. Fielding, T. Laveist, L. N. Borrell, R. Manderscheid and A. Troutman. 2011. "Health Disparities and Health Equity: The Issue Is Justice." *Am J Public Health* 101 Suppl 1:S149-55. doi: 10.2105/ajph.2010.300062.

Braveman, Paula, Susan Egerter and David R Williams. 2011. "The Social Determinants of Health: Coming of Age." *Annu Rev Public Health* 32:381-98.

Braveman, Paula. 2014. "What Are Health Disparities and Health Equity? We Need to Be Clear." *Public Health Reports* 129(Suppl 2):5-8.

Braveman, Paula A, Catherine Cubbin, Susan Egerter, David R Williams and Elsie Pamuk. 2010. "Socioeconomic Disparities in Health in the United States: What the Patterns Tell Us." *Am J Public Health* 100(S1):S186-S96.

Bronfenbrenner, U. 1977. "Toward an Experimental Ecology of Human Development." *American Psychologist*:513-31.

Bronfenbrenner, U. 1994. "Ecological Models of Human Development." in *International Encyclopedia of Education*, Vol. 3. Oxford: Elsevier.

Burton, R. F. 2007. "Why Is the Body Mass Index Calculated as Mass/Height2, Not as Mass/Height3?". *Ann Hum Biol* 34(6):656-63. doi: 10.1080/03014460701732962.

California Housing Partnership Corporation. 2014. "How Los Angeles County's Housing Market Is Failing to Meet the Needs of Low-Income Families." Vol.

Campos, B., JB Ullman, A Aguilera and C Dunkel Schetter. 2014. "Familism and Psychological Health: The Intervening Role of Closeness and Social Support.". *Cultural Diversity and Ethnic Minority Psychology* 20(2):191-201.

Caprio, Sonia, Stephen R Daniels, Adam Drewnowski, Francine R Kaufman, Lawrence A Palinkas, Arlan L Rosenbloom and Jeffrey B Schwimmer. 2008. "Influence of Race, Ethnicity, and Culture on Childhood Obesity: Implications for Prevention and Treatment a Consensus Statement of Shaping America's Health and the Obesity Society." *Diabetes care* 31(11):2211-21.

Carson, V., J. C. Spence, N. Cutumisu and L. Cargill. 2010. "Association between Neighborhood Socioeconomic Status and Screen Time among Pre-School Children: A Cross-Sectional Study." *BMC public health* 10:367. doi: 10.1186/1471-2458-10-367.

Carvalhal, M. M., M. C. Padez, P. A. Moreira and V. M. Rosado. 2007. "Overweight and Obesity Related to Activities in Portuguese Children, 7-9 Years." *Eur J Public Health* 17(1):42-6. doi: 10.1093/eurpub/ckl093.

CDC. 2014. "The Prevalence of Obesity among Low-Income Children Aged 2 through 4 Years, by State and Income, 2011."

CDC. 2016, "A Sas Program for the 2000 Cdc Growth Charts (Ages 0 to <20 Years)". Retrieved June 25, 2016, (http://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm).

Chandola, Tarani, Paul Clarke, JN Morris and David Blane. 2006. "Pathways between Education and Health: A Causal Modelling Approach." *Journal of the Royal Statistical Society: Series A (Statistics in Society)* 169(2):337-59.

Chaparro, M. P., M. C. Wang and S. E. Whaley. 2013. "Neighborhood Obesity Trends among 2-5 Year Old Children Participating in the Special Supplemental Nutrition Program for Women, Infants and Children (Wic) in Los Angeles County, 2002-2011." Vol. Los Angeles, Ca: First 5 LA.

Chaparro, M. P., B. A. Langellier, M. C. Wang, M. Koleilat and S. E. Whaley. 2015. "Effects of Parental Nativity and Length of Stay in the Us on Fruit and Vegetable Intake among Wic-Enrolled Preschool-Aged Children." *J Immigr Minor Health* 17(2):333-8. doi: 10.1007/s10903-014-0097-5.

Chaparro, M.P., S.E. Whaley, C.M. Crespi, M. Koleilat, T.Z. Nobari, E. Seto and M. C. Wang. 2014. "Influences of the Neighborhood Food Environment on Adiposity of Low-Income Preschool-Aged Children in Los Angeles County: A Longitudinal Study.". *J Epidemiol Community Health* Revise and resubmit.

Chiasson, M. A., S. E. Findley, J. P. Sekhobo, R. Scheinmann, L. S. Edmunds, A. S. Faly and N. J. McLeod. 2013. "Changing Wic Changes What Children Eat." *Obesity (Silver Spring)* 21(7):1423-9. doi: 10.1002/oby.20295.

Chivers, Paola, Helen Parker, Max Bulsara, Lawrence Beilin and Beth Hands. 2012. "Parental and Early Childhood Influences on Adolescent Obesity: A Longitudinal Study." *Early Child Development and Care* 182(8):1071-87.

ChooseHealthLA! 2011. "Early Childhood Obesity Prevention Initiative." Vol.

Coburn, Shayna S., N. A. Gonzales, L. J. Luecken and K. A. Crnic. 2016. "Multiple Domains of Stress Predict Postpartum Depressive Symptoms in Low-Income Mexican American Women: The Moderating Effect of Social Support." *Archives of Women's Mental Health*:1-10. doi: 10.1007/s00737-016-0649-x.

Cohen, Alison K., Manisha Rai, David H. Rehkopf and Barbara Abrams. 2013. "Educational Attainment and Obesity: A Systematic Review." *Obes Rev* 14(12):989-1005. doi: 10.1111/obr.12062.

Cohen, S. , R.C. Kessler and U.L. Gordon. 1995. "Strategies for Measuring Stress in Studies of Psychiatric and Physical Disorder." Pp. 3-26 in *Measuring Stress: A Guide for Health and Social Scientists*, edited by K. R. Cohen S, Gordon UL,. New York, NY: Oxford University Press.

Cohen, Sheldon and Thomas A Wills. 1985. "Stress, Social Support, and the Buffering Hypothesis." *Psychological bulletin* 98(2):310.

Conger, Katherine Jewsbury, Martha A Rueter and Rand D Conger. 2000. "The Role of Economic Pressure in the Lives of Parents and Their Adolescents: The Family Stress Model." Pp. 201-23 in *Negotiating Adolescence in Times of Social Change*, edited by L. J. E. Crockett and R. K. E. Silbereisen. New York, NY: Cambridge University Press.

Conger, Rand D., Lora Ebert Wallace, Yumei Sun, Ronald L. Simons, Vonnie C. McLoyd and Gene H. Brody. 2002. "Economic Pressure in African American Families: A Replication and Extension of the Family Stress Model." *Developmental Psychology* 38(2):179-93. doi: http://dx.doi.org/10.1037/0012-1649.38.2.179.

Crespi, C. M., V. H. Alfonso, S. E. Whaley and M. C. Wang. 2012. "Validity of Child Anthropometric Measurements in the Special Supplemental Nutrition Program for Women, Infants, and Children." *Pediatr Res* 71(3):286-92. doi: 10.1038/pr.2011.37.

Cutler, David, Edward Glaeser and Jesse Shapiro. 2003. "Why Have Americans Become More Obese?" Vol.: National Bureau of Economic Research.

Cutler, David M and Adriana Lleras-Muney. 2006. "Education and Health: Evaluating Theories and Evidence." Vol.: National Bureau of Economic Research.

Cutler, David M., Wei Huang and Adriana Lleras-Muney. 2015. "When Does Education Matter? The Protective Effect of Education for Cohorts Graduating in Bad Times." *Social science & medicine* 127:63-73. doi: http://dx.doi.org/10.1016/j.socscimed.2014.07.056.

Cutts, D. B., A. F. Meyers, M. M. Black, P. H. Casey, M. Chilton, J. T. Cook, J. Geppert, S. Ettinger de Cuba, T. Heeren, S. Coleman, R. Rose-Jacobs and D. A. Frank. 2011. "Us Housing Insecurity and the Health of Very Young Children." *Am J Public Health* 101(8):1508-14. doi: 10.2105/ajph.2011.300139.

Dalenius K, Borland E, Smith B, Polhamus B and Grummer-Strawn L. 2012. "Pediatric Nutrition Surveillance 2010 Report." Vol. Atlanta: U.S. Department of Health and Human Services,

Centers for Disease Control and Prevention,.

Dallman, M. F. 2010. "Stress-Induced Obesity and the Emotional Nervous System." *Trends Endocrinol Metab* 21(3):159-65. doi: 10.1016/j.tem.2009.10.004.

Daniels, Stephen R. and Sandra G. Hassink. 2015. "The Role of the Pediatrician in Primary Prevention of Obesity." *Pediatrics*. doi: 10.1542/peds.2015-1558.

Darmon, Nicole and Adam Drewnowski. 2008. "Does Social Class Predict Diet Quality?". *Am J Clin Nutr* 87(5):1107-17.

Darmon, Nicole and Adam Drewnowski. 2015. "Contribution of Food Prices and Diet Cost to Socioeconomic Disparities in Diet Quality and Health: A Systematic Review and Analysis." *Nutrition Reviews* 73(10):643-60. doi: 10.1093/nutrit/nuv027.

Davison, K. K. and L. L. Birch. 2001. "Childhood Overweight: A Contextual Model and Recommendations for Future Research." *Obes Rev* 2(3):159-71.

Davison, Kirsten K, Janine M Jurkowski and Hal A Lawson. 2013. "Reframing Family-Centred Obesity Prevention Using the Family Ecological Model." *Public health nutrition* 16(10):1861-69.

De Onis, Mercedes, Monika Blössner and Elaine Borghi. 2010. "Global Prevalence and Trends of Overweight and Obesity among Preschool Children." *Am J Clin Nutr* 92(5):1257-64.

Demment, Margaret M, Jere D Haas and Christine M Olson. 2014. "Changes in Family Income Status and the Development of Overweight and Obesity from 2 to 15 Years: A Longitudinal Study." *BMC public health* 14(1):417.

Dennison, B. A., T. A. Erb and P. L. Jenkins. 2002. "Television Viewing and Television in Bedroom Associated with Overweight Risk among Low-Income Preschool Children." *Pediatrics* 109(6):1028-35.

Diez Roux, Ana V and Christina Mair. 2010. "Neighborhoods and Health." *Annals of the New York Academy of Sciences* 1186(1):125-45.

Dubois, L. and M. Girard. 2006. "Early Determinants of Overweight at 4.5 Years in a Population-Based Longitudinal Study." *Int J Obes (Lond)* 30(4):610-7. doi: 10.1038/sj.ijo.0803141.

Duncan, Greg J., Mary C. Daly, Peggy McDonough and David R. Williams. 2002. "Optimal Indicators of Socioeconomic Status for Health Research." *Am J Public Health* 92(7):1151-57.

Eisenmann, JC, C Gundersen, BJ Lohman, S Garasky and SD. Stewart. 2011. "Is Food Insecurity Related to Overweight and Obesity in Children and Adolescents? A Summary of Studies, 1995-2009." *Obes Rev* 1 2(5):e73-83.

Eknoyan, Garabed. 2008. "Adolphe Quetelet (1796–1874)—the Average Man and Indices of Obesity." *Nephrology Dialysis Transplantation* 23(1):47-51. doi: 10.1093/ndt/gfm517.

Elo, I. T. and S. H. Preston. 1996. "Educational Differentials in Mortality: United States, 1979-85." *Soc Sci Med* 42(1):47-57.

Evans, Gary W. 2004. "The Environment of Childhood Poverty." *American Psychologist* 59(2):77.

Evans, Gary W., Henry N. Ricciuti, Steven Hope, Ingrid Schoon, Robert H. Bradley, Robert F. Corwyn and Cindy Hazan. 2010. "Crowding and Cognitive Development: The Mediating Role of Maternal Responsiveness among 36-Month-Old Children." *Environment and Behavior* 42(1):135-48. doi: http://dx.doi.org/10.1177/0013916509333509.

Special Supplemental Nutrition Program for Women, Infants and Children (Wic): Revisions in the Wic Food Packages (Federal Register 2007).

Feeding America. nd. "In Short Supply: American Families Struggle to Secure Everyday Essentials."

Field Research Corporation. 2014. "A Summary of the Survey Methods Used to Conduct the 2014 Wic Participants Survey Conducted on Behalf of Public Health Foundation Enterprises (Phfe)." Vol.: Field Research Corporation.

Finkelstein, Eric A, Justin G Trogdon, Joel W Cohen and William Dietz. 2009. "Annual Medical Spending Attributable to Obesity: Payer-and Service-Specific Estimates." *Health affairs* 28(5):w822-w31.

First 5 LA. 2014. "Reducing Early Childhood Obesity in Los Angeles County."

First 5 LA. n,d. "Appendix A. First 5 La Projects Related to Childhood Obesity Prevention." Vol.

Foss, B. and S. M. Dyrstad. 2011. "Stress in Obesity: Cause or Consequence?". *Med Hypotheses* 77(1):7-10. doi: 10.1016/j.mehy.2011.03.011.

Frederick, Carl B., Kaisa Snellman and Robert D. Putnam. 2014. "Increasing Socioeconomic Disparities in Adolescent Obesity." *Proceedings of the National Academy of Sciences* 111(4):1338-42. doi: 10.1073/pnas.1321355110.

Freedman, D. S., L. K. Khan, M. K. Serdula, W. H. Dietz, S. R. Srinivasan and G. S. Berenson. 2005. "The Relation of Childhood Bmi to Adult Adiposity: The Bogalusa Heart Study." *Pediatrics* 115(1):22-7. doi: 10.1542/peds.2004-0220.

Freedman, D.S., L.K. Khan, Dietz WH, Srinivasan S.A. and G.S. Berenson. 2001. "Relationship of Childhood Obesity to Coronary Heart Disease Risk Factors in Adulthood: The Bogalusa Heart Study." *Pediatrics* 108(712-718).

Fryar, Cheryl D, Margaret D Carroll and Cynthia L Ogden. 2012. "Prevalence of Obesity among Children and Adolescents: United States, Trends 1963–1965 through 2009–2010." *National Center for Health Statistics*:1960-2002.

Fuchs, Victor R. 2004. "Reflections on the Socio-Economic Correlates of Health." *Journal of health economics* 23(4):653-61.

Galea, S., M. Tracy, K. J. Hoggatt, C. Dimaggio and A. Karpati. 2011. "Estimated Deaths Attributable to Social Factors in the United States." *Am J Public Health* 101(8):1456-65. doi: 10.2105/ajph.2010.300086.

Garasky, Sa, S. D. Stewart, C. Gundersen, B. J. Lohman and J. C. Eisenmann. 2009. "Family Stressors and Child Obesity." *Soc Sci Res* 38(4):755-66.

Garn, S. M., W. R. Leonard and V. M. Hawthorne. 1986. "Three Limitations of the Body Mass Index." *Am J Clin Nutr* 44(6):996-7.

Gee, G. C., A. Ro, A. Gavin and D. T. Takeuchi. 2008. "Disentangling the Effects of Racial and Weight Discrimination on Body Mass Index and Obesity among Asian Americans." *Am J Public Health* 98(3):493-500. doi: 10.2105/ajph.2007.114025.

Gibson, L. Y., S. M. Byrne, E. A. Davis, E. Blair, P. Jacoby and S. R. Zubrick. 2007. "The Role of Family and Maternal Factors in Childhood Obesity." *Med J Aust* 186(11):591-5.

Glantz, S.A. and B.K. Slinker. 2001. *Primer of Applied Regression and Analysis of Variance. 2nd Ed.*: McGraw-Hill, Inc.

Gross, H. E., D. S. Shaw, R. A. Burwell and D. S. Nagin. 2009. "Transactional Processes in Child Disruptive Behavior and Maternal Depression: A Longitudinal Study from Early Childhood to Adolescence." *Dev Psychopathol* 21(1):139-56. doi: 10.1017/s0954579409000091.

Grow, H Mollie Greves, Andrea J Cook, David E Arterburn, Brian E Saelens, Adam Drewnowski and Paula Lozano. 2010. "Child Obesity Associated with Social Disadvantage of Children’s Neighborhoods." *Social science & medicine* 71(3):584-91.

Gundersen, C., D. Mahatmya, S. Garasky and B. Lohman. 2011. "Linking Psychosocial Stressors and Childhood Obesity." *Obes Rev* 12(5):e54-63. doi: 10.1111/j.1467-789X.2010.00813.x.

Gunnar, M. and K. Quevedo. 2007. "The Neurobiology of Stress and Development." *Annu Rev Psychol* 58:145-73. doi: 10.1146/annurev.psych.58.110405.085605.

Guo, S. S. and W. C. Chumlea. 1999. "Tracking of Body Mass Index in Children in Relation to Overweight in Adulthood." *Am J Clin Nutr* 70(1):145s-8s.

Guo, S. S., W. Wu, W. C. Chumlea and A. F. Roche. 2002. "Predicting Overweight and Obesity in Adulthood from Body Mass Index Values in Childhood and Adolescence." *Am J Clin Nutr* 76(3):653-8.

Harkness, Joseph and Sandra J Newman. 2005. "Housing Affordability and Children's Well-Being: Evidence from the National Survey of America's Families." *Housing Policy Debate* 16(2):223-55.

Harvey, E. A. and L. A. Metcalfe. 2012. "The Interplay among Preschool Child and Family Factors and the Development of Odd Symptoms." *J Clin Child Adolesc Psychol* 41(4):458-70. doi: 10.1080/15374416.2012.673161.

Hayes, A.F. 2009. "Beyond Baron and Kenny: Statistical Mediation Analysis in the New Millennium." *Communication Monographs* 76(4):408-20.

Hayes, A.F. 2015, "The Process Macro for Spss and Sas". Retrieved February 26, 2015, (http://www.processmacro.org/).

Health and Human Services. 2005. "Childhood Obesity." Vol.

Herbert, CE, DT McCue and R Sanchez-Moyano. 2013. "Is Homeownership Still an Effective Means of Building Wealth for Low-Income and Minority Households? (Was It Ever?)." Vol. HBTL-06. Boston, MA: Harvard University, Joint Center for Housing Studies.

Hill, James O. 2006. "Understanding and Addressing the Epidemic of Obesity: An Energy Balance Perspective." *Endocrine reviews* 27(7):750-61.

Hsu, T. 2012. "Independent Restaurants Hardest Hit by Slow Restaurant Traffic." in *LA Times*.

Hunte, Haslyn E. R. and David R. Williams. 2009. "The Association between Perceived Discrimination and Obesity in a Population-Based Multiracial and Multiethnic Adult Sample." *Am J Public Health* 99(7):1285-92. doi: 10.2105/AJPH.2007.128090.

Institute of Medicine. 2006. "Food Marketing to Children and Youth: Threat or Opportunity?" Vol. Washington, DC: National Academy of Sciences Press.

Institute of Medicine. 2013. *Evaluating Obesity Prevention Efforts: A Plan for Measuring Progress*. Washington, DC: The National Academies Press.

Jaaskelainen, A., N. Nevanpera, J. Remes, F. Rahkonen, M. R. Jarvelin and J. Laitinen. 2014. "Stress-Related Eating, Obesity and Associated Behavioural Traits in Adolescents: A Prospective Population-Based Cohort Study." *BMC public health* 14:321. doi: 10.1186/1471-2458-14-321.

Joint Center for Housing Studies. 2011. "The State of the Nation's Housing 2011." Vol.: Harvard University,.

Joint Center for Housing Studies. 2014. "The State of the Nation's Housing 2014." Vol.: Harvard University,.

Joint Center for Housing Studies. 2015. "The State of the Nation's Housing 2015." Vol.: Harvard University,.

Jones-Smith, Jessica C, Marlowe Gates Dieckmann, Laura Gottlieb, Jessica Chow and Lia CH Fernald. 2014. "Socioeconomic Status and Trajectory of Overweight from Birth to Mid-Childhood: The Early Childhood Longitudinal Study-Birth Cohort." *PLoS One* 9(6):e100181.

Jones, A., M. Charakida, E. Falaschetti, A. D. Hingorani, N. Finer, S. Masi, A. E. Donald, D. A. Lawlor, G. D. Smith and J. E. Deanfield. 2012. "Adipose and Height Growth through Childhood and Blood Pressure Status in a Large Prospective Cohort Study." *Hypertension* 59(5):919-25. doi: 10.1161/hypertensionaha.111.187716.

Juhola, J., C. G. Magnussen, J. S. Viikari, M. Kahonen, N. Hutri-Kahonen, A. Jula, T. Lehtimaki, H. K. Akerblom, M. Pietikainen, T. Laitinen, E. Jokinen, L. Taittonen, O. T. Raitakari and M. Juonala. 2011. "Tracking of Serum Lipid Levels, Blood Pressure, and Body Mass Index from Childhood to Adulthood: The Cardiovascular Risk in Young Finns Study." *J Pediatr* 159(4):584-90. doi: 10.1016/j.jpeds.2011.03.021.

Kant, A. K. and B. I. Graubard. 2013. "Family Income and Education Were Related with 30-Year Time Trends in Dietary and Meal Behaviors of American Children and Adolescents." *J Nutr* 143(5):690-700. doi: 10.3945/jn.112.165258.

Kenkel, Donald S. 1991. "Health Behavior, Health Knowledge, and Schooling." *Journal of Political Economy*:287-305.

Kimbro, R. T. and J. T. Denney. 2013. "Neighborhood Context and Racial/Ethnic Differences in Young Children's Obesity: Structural Barriers to Interventions." *Soc Sci Med* 95:97-105. doi: 10.1016/j.socscimed.2012.09.032.

Kimbro, Rachel Tolbert, Jeanne Brooks-Gunn and Sara McLanahan. 2011. "Young Children in Urban Areas: Links among Neighborhood Characteristics, Weight Status, Outdoor Play, and Television Watching." *Social science & medicine* 72(5):668-76.

Kirkpatrick, SI and V. Tarasuk. 2011. "Housing Circumstances Are Associated with Household Food Access among Low-Income Urban Families." *J Urban Health* 88(2):284-96.

Kit, B.K., C.L. Ogden and K. M. Flegal. 2014. "Epidemiology of Obesity." Pp. 2229-62 in *Handbook of Epidemiology, 2nd Edition,*, edited by W. Ahrens and I. Pigeot. New York: Springer Science+Business Media.

Koleilat, Maria and Shannon E. Whaley. 2016. "Reliability and Validity of Food Frequency Questions to Assess Beverage and Food Group Intakes among Low-Income 2- to 4-Year-Old Children." *J Acad Nutr Diet*. doi: 10.1016/j.jand.2016.02.014.

Kranjac, A. W. and R. L. Wagmiller. 2016. "Association between Age and Obesity over Time." *Pediatrics* 137(5). doi: 10.1542/peds.2015-2096.

Kroenke, K., R. L. Spitzer and J. B. Williams. 2003. "The Patient Health Questionnaire-2: Validity of a Two-Item Depression Screener." *Med Care* 41(11):1284-92. doi: 10.1097/01.mlr.0000093487.78664.3c.

Kuczmarski, R.J., C.L. Ogden, S.S. Guo, L.M. Grummer-Strawn, K.M. Flegal, Z. Mei, R. Wei, L.R. Curtin, A.F. Roche and C.L. Johnson. 2002. "2000 Cdc Growth Charts for the United States: Methods and Development." *Vital Health Stat 11* 246:1-190.

LA County WIC Data. 2016, "Los Angeles County Wic Data: Obesity Topic". Retrieved June 1, 2016, (http://lawicdata.org/topics/obesity/).

LACDPH. 2015. "Housing and Health in Los Angeles County." Vol. Los Angeles, Ca.: Los Angeles County Department of Public Health.

Lake, Amelia and Tim Townshend. 2006. "Obesogenic Environments: Exploring the Built and Food Environments." *The Journal of the Royal society for the Promotion of Health* 126(6):262-67.

Lampard, A. M., J. M. Jurkowski and K. K. Davison. 2013. "The Family Context of Low-Income Parents Who Restrict Child Screen Time." *Child Obes* 9(5):386-92. doi: 10.1089/chi.2013.0043.

Lampard, Amy M., Rebecca L. Franckle and Kirsten K. Davison. 2014. "Maternal Depression and Childhood Obesity: A Systematic Review." *Preventive Medicine* 59(0):60-67. doi: http://dx.doi.org/10.1016/j.ypmed.2013.11.020.

Langellier, B. A., M. P. Chaparro, M. C. Wang, M. Koleilat and S. E. Whaley. 2014. "The New Food Package and Breastfeeding Outcomes among Women, Infants, and Children Participants in Los Angeles County." *Am J Public Health* 104 Suppl 1:S112-8. doi: 10.2105/ajph.2013.301330.

Lee, H., M. Andrew, A. Gebremariam, J. C. Lumeng and J. M. Lee. 2014. "Longitudinal Associations between Poverty and Obesity from Birth through Adolescence." *Am J Public Health* 104(5):e70-6. doi: 10.2105/ajph.2013.301806.

Lee, Hedwig, Kathleen Mullan Harris and Penny Gordon-Larsen. 2009. "Life Course Perspectives on the Links between Poverty and Obesity During the Transition to Young Adulthood." *Population research and policy review* 28(4):505-32. doi: 10.1007/s11113-008-9115-4.

Leventhal, Tama and Sandra Newman. 2010. "Housing and Child Development." *Children and Youth Services Review* 32(9):1165-74.

Linabery, A. M., R. W. Nahhas, W. Johnson, A. C. Choh, B. Towne, A. O. Odegaard, S. A. Czerwinski and E. W. Demerath. 2013. "Stronger Influence of Maternal Than Paternal Obesity on Infant and Early Childhood Body Mass Index: The Fels Longitudinal Study." *Pediatr Obes* 8(3):159-69. doi: 10.1111/j.2047-6310.2012.00100.x.

Link, Bruce G and Jo Phelan. 1995. "Social Conditions as Fundamental Causes of Disease." *Journal of Health and Social Behavior*:80-94.

Litonjua, Augusto A. and Diane R. Gold. 2008. "Asthma and Obesity: Common Early-Life Influences in the Inception of Disease." *Journal of Allergy and Clinical Immunology* 121(5):1075-84. doi: http://dx.doi.org/10.1016/j.jaci.2008.03.005.

Lleras-Muney, Adriana. 2005. "The Relationship between Education and Adult Mortality in the United States." *The Review of Economic Studies* 72(1):189-221.

Lobstein, T., L. Baur and R. Uauy. 2004. "Obesity in Children and Young People: A Crisis in Public Health." *Obes Rev* 5 Suppl 1:4-104. doi: 10.1111/j.1467-789X.2004.00133.x.

Lovasi, G. S., M. A. Hutson, M. Guerra and K. M. Neckerman. 2009. "Built Environments and Obesity in Disadvantaged Populations." *Epidemiol Rev* 31:7-20. doi: 10.1093/epirev/mxp005.

Lumeng, J. C., A. Miller, K. E. Peterson, N. Kaciroti, J. Sturza, K. Rosenblum and D. M. Vazquez. 2014. "Diurnal Cortisol Pattern, Eating Behaviors and Overweight in Low-Income Preschool-Aged Children." *Appetite* 73:65-72. doi: 10.1016/j.appet.2013.10.016.

Lundahl, A., T. D. Nelson, T. R. Van Dyk and T. West. 2013. "Psychosocial Stressors and Health Behaviors: Examining Sleep, Sedentary Behaviors, and Physical Activity in a Low-Income Pediatric Sample." *Clin Pediatr (Phila)* 52(8):721-9. doi: 10.1177/0009922813482179.

Ma, C. T., L. Gee and M. B. Kushel. 2008a. "Associations between Housing Instability and Food Insecurity with Health Care Access in Low-Income Children." *Ambul Pediatr* 8(1):50-7. doi: 10.1016/j.ambp.2007.08.004.

Ma, Christine T., Lauren Gee and Margot B. Kushel. 2008b. "Associations between Housing Instability and Food Insecurity with Health Care Access in Low-Income Children." *Ambulatory Pediatrics* 8(1):50-57. doi: http://dx.doi.org/10.1016/j.ambp.2007.08.004.

MacKinnon, D.P. 2008. *Introduction to Statistical Mediation Analysis*. New York, NY: Psychology Press.

Maheswaran, D., Y. Zeng, M. Chan-Yeung, J. Scott, A. Osornio-Vargas, A. B. Becker and A. L. Kozyrskyj. 2014. "Exposure to Beta-(1,3)-D-Glucan in House Dust at Age 7-10 Is Associated with Airway Hyperresponsiveness and Atopic Asthma by Age 11-14." *PLoS One* 9(6):e98878. doi: 10.1371/journal.pone.0098878.

Marshall, S. J., S. J. Biddle, T. Gorely, N. Cameron and I. Murdey. 2004. "Relationships between Media Use, Body Fatness and Physical Activity in Children and Youth: A Meta-Analysis." *Int J Obes Relat Metab Disord* 28(10):1238-46. doi: 10.1038/sj.ijo.0802706.

Mason, K. E., E. Baker, T. Blakely and R. J. Bentley. 2013. "Housing Affordability and Mental Health: Does the Relationship Differ for Renters and Home Purchasers?". *Soc Sci Med* 94:91-7. doi: 10.1016/j.socscimed.2013.06.023.

May, A. L., D. Freedman, B. Sherry and H. M. Blanck. 2013. "Obesity - United States, 1999-2010." *MMWR Surveill Summ* 62 Suppl 3:120-8.

McConnell, D., R. Breitkreuz and A. Savage. 2011. "From Financial Hardship to Child Difficulties: Main and Moderating Effects of Perceived Social Support." *Child Care Health Dev* 37(5):679-91. doi: 10.1111/j.1365-2214.2010.01185.x.

Metallinos-Katsaras, E., B. Sherry and J. Kallio. 2009. "Food Insecurity Is Associated with Overweight in Children Younger Than 5 Years of Age." *J Am Diet Assoc* 109(10):1790-4. doi: 10.1016/j.jada.2009.07.007.

Metallinos-Katsaras, E., A. Must and K. Gorman. 2012. "A Longitudinal Study of Food Insecurity on Obesity in Preschool Children." *J Acad Nutr Diet* 112(12):1949-58. doi: 10.1016/j.jand.2012.08.031.

Michels, N., I. Sioen, L. Boone, C. Braet, B. Vanaelst, I. Huybrechts and S. De Henauw. 2015. "Longitudinal Association between Child Stress and Lifestyle." *Health Psychol* 34(1):40-50. doi: 10.1037/hea0000108.

Miller, A. L., C. Clifford, J. Sturza, K. Rosenblum, D. M. Vazquez, N. Kaciroti and J. C. Lumeng. 2013. "Blunted Cortisol Response to Stress Is Associated with Higher Body Mass Index in Low-Income Preschool-Aged Children." *Psychoneuroendocrinology* 38(11):2611-7. doi: 10.1016/j.psyneuen.2013.06.014.

Mirowsky, J. and C.E. Ross. 2003. *Education, Social Status, and Health*. New York: Walter de Gruyter.

Monroe, S. M. 2008. "Modern Approaches to Conceptualizing and Measuring Human Life Stress." *Annu Rev Clin Psychol* 4:33-52. doi: 10.1146/annurev.clinpsy.4.022007.141207.

Moore, L. V. and A. V. Diez Roux. 2006. "Associations of Neighborhood Characteristics with the Location and Type of Food Stores." *Am J Public Health* 96(2):325-31. doi: 10.2105/ajph.2004.058040.

Morland, K., S. Wing, A. Diez Roux and C. Poole. 2002. "Neighborhood Characteristics Associated with the Location of Food Stores and Food Service Places." *Am J Prev Med* 22(1):23-9.

Nader, P. R., M. O'Brien, R. Houts, R. Bradley, J. Belsky, R. Crosnoe, S. Friedman, Z. Mei and E. J. Susman. 2006. "Identifying Risk for Obesity in Early Childhood." *Pediatrics* 118(3):e594-601. doi: 10.1542/peds.2005-2801.

NCHS. 2012. "Health, United States, 2011: With Special Feature on Socioeconomic Status and Health." Vol. Hyattsville, MD.: National Center for Health Statistics.

Newland, R. P., K. A. Crnic, M. J. Cox and W. R. Mills-Koonce. 2013. "The Family Model Stress and Maternal Psychological Symptoms: Mediated Pathways from Economic Hardship to Parenting." *J Fam Psychol* 27(1):96-105. doi: 10.1037/a0031112.

Ng, S. W., M. M. Slining and B. M. Popkin. 2014. "Turning Point for Us Diets? Recessionary Effects or Behavioral Shifts in Foods Purchased and Consumed." *Am J Clin Nutr* 99(3):609-16. doi: 10.3945/ajcn.113.072892.

Nguyen-Rodriguez, S. T., J. B. Unger and D. Spruijt-Metz. 2009. "Psychological Determinants of Emotional Eating in Adolescence." *Eat Disord* 17(3):211-24. doi: 10.1080/10640260902848543.

NHLBI and NIDDKD. 1998. "Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults. The Evidence Report." Vol.: National Institutes of Health.

Nobari, T. Z., M. C. Wang, M. P. Chaparro, C. M. Crespi, M. Koleilat and S. E. Whaley. 2013. "Immigrant Enclaves and Obesity in Preschool-Aged Children in Los Angeles County." *Soc Sci Med* 92:1-8. doi: 10.1016/j.socscimed.2013.05.019.

Nobari, T. Z., E. Blumenberg, M. P. Chaparro, E. Seto and M. C. Wang. 2014. "The Food Environment of Immigrant Enclaves in Los Angeles County." Paper presented at the Population Association of America, Boston, MA.

Nobari, T. Z., M. C. Wang and S. E. Whaley. 2015. "Asian American Mothers' Perception of Their Children's Weight: A Comparison with Other Racial/Ethnic Groups in Los Angeles." *Ethn Dis* 25(1):52-7.

Nobari, TZ, MC Wang and PB Crawford. 2014. "The Impact of Stress on Adolescent Obesity: Findings from the Nghs Study." Paper presented at the American Public Health Association, November 2014, New Orleans.

Odoms-Young, A. M., A. Kong, L. A. Schiffer, S. J. Porter, L. Blumstein, S. Bess, M. L. Berbaum and M. L. Fitzgibbon. 2014. "Evaluating the Initial Impact of the Revised Special Supplemental Nutrition Program for Women, Infants, and Children (Wic) Food Packages on Dietary Intake and Home Food Availability in African-American and Hispanic Families." *Public Health Nutr* 17(1):83-93. doi: 10.1017/s1368980013000761.

Ogden, C. L. 2004. "Defining Overweight in Children Using Growth Charts." *Md Med* 5(3):19-21.

Ogden, C. L., M. M. Lamb, M. D. Carroll and K. M. Flegal. 2010a. "Obesity and Socioeconomic Status in Adults: United States, 2005-2008." *NCHS Data Brief* (50):1-8.

Ogden, C. L., M. M. Lamb, M. D. Carroll and K. M. Flegal. 2010b. "Obesity and Socioeconomic Status in Children and Adolescents: United States, 2005-2008." *NCHS Data Brief* (51):1-8.

Ogden, C. L., M. D. Carroll, B. K. Kit and K. M. Flegal. 2012. "Prevalence of Obesity and Trends in Body Mass Index among Us Children and Adolescents, 1999-2010." *Jama* 307(5):483-90. doi: 10.1001/jama.2012.40.

Ogden, C. L., M. D. Carroll, B. K. Kit and K. M. Flegal. 2014. "Prevalence of Childhood and Adult Obesity in the United States, 2011-2012." *Jama* 311(8):806-14. doi: 10.1001/jama.2014.732.

Ortega, Alexander N., Stephanie L. Albert, Mienah Z. Sharif, Brent A. Langellier, Rosa Elena Garcia, Deborah C. Glik, Ron Brookmeyer, Alec M. Chan-Golston, Scott Friedlander and Michael L. Prelip. 2015. "Proyecto Mercadofresco: A Multi-Level, Community-Engaged Corner Store Intervention in East Los Angeles and Boyle Heights." *Journal of community health* 40(2):347-56. doi: 10.1007/s10900-014-9941-8.

Pan, L., H. M. Blanck, B. Sherry, K. Dalenius and L. M. Grummer-Strawn. 2012. "Trends in the Prevalence of Extreme Obesity among Us Preschool-Aged Children Living in Low-Income Families, 1998-2010." *Jama* 308(24):2563-65. doi: 10.1001/jama.2012.108099.

Pan, Liping, Lisa C. McGuire, Heidi M. Blanck, Ashleigh L. May-Murriel and Laurence M. Grummer-Strawn. 2015. "Racial/Ethnic Differences in Obesity Trends among Young Low-Income Children." *Am J Prev Med* 48(5):570-74. doi: 10.1016/j.amepre.2014.11.009.

Pardini, D. A., P. J. Fite and J. D. Burke. 2008. "Bidirectional Associations between Parenting Practices and Conduct Problems in Boys from Childhood to Adolescence: The Moderating Effect of Age and African-American Ethnicity." *J Abnorm Child Psychol* 36(5):647-62. doi: 10.1007/s10802-007-9162-z.

Parks, E. P., S. Kumanyika, R. H. Moore, N. Stettler, B. H. Wrotniak and A. Kazak. 2012. "Influence of Stress in Parents on Child Obesity and Related Behaviors." *Pediatrics* 130(5):e1096-104. doi: 10.1542/peds.2012-0895.

Parvanta, SA, JD Brown, S Du, CR Zimmer, X Zhao and F Zhai. 2010. "Television Use and Snacking Behaviors among Children and Adolescents in China." *J Adolesc Health* 46:339–45.

PHFE-WIC and First 5 LA. 2015. "Los Angeles County Wic Survey." edited by LA County WIC Data.

Pollack, C. E., S. Chideya, C. Cubbin, B. Williams, M. Dekker and P. Braveman. 2007. "Should Health Studies Measure Wealth? A Systematic Review." *Am J Prev Med* 33(3):250-64. doi: 10.1016/j.amepre.2007.04.033.

Pollack, C. E., Susan Egerter, T. Sadegh-Nobari, M. Dekker and Paula Braveman. 2008. "Housing and Health Issue Brief." Vol. *Issue Briefs of the Commission to Build a Healthier America.* New Jersey: Robert Wood Johnson Foundation.

Pollack, C. E., B. A. Griffin and J. Lynch. 2010. "Housing Affordability and Health among Homeowners and Renters." *Am J Prev Med* 39(6):515-21. doi: 10.1016/j.amepre.2010.08.002.

Popkin, B. M. 2006. "Global Nutrition Dynamics: The World Is Shifting Rapidly toward a Diet Linked with Noncommunicable Diseases." *Am J Clin Nutr* 84(2):289-98.

Quigley, John M and Steven Raphael. 2004. "Is Housing Unaffordable? Why Isn't It More Affordable?". *The Journal of Economic Perspectives* 18(1):191-214.

Quinones, S. 2015. "A Change in the Landscape: L.A.'S Parks No Longer Belong to Street Gangs." in *LA Times*.

Raspopow, K., A. Abizaid, K. Matheson and H. Anisman. 2010. "Psychosocial Stressor Effects on Cortisol and Ghrelin in Emotional and Non-Emotional Eaters: Influence of Anger and Shame." *Horm Behav* 58(4):677-84. doi: 10.1016/j.yhbeh.2010.06.003.

Raspopow, K., A. Abizaid, K. Matheson and H. Anisman. 2014. "Anticipation of a Psychosocial Stressor Differentially Influences Ghrelin, Cortisol and Food Intake among Emotional and Non-Emotional Eaters." *Appetite* 74:35-43. doi: 10.1016/j.appet.2013.11.018.

Rauh, V. A., P. J. Landrigan and L. Claudio. 2008. "Housing and Health: Intersection of Poverty and Environmental Exposures." *Ann N Y Acad Sci* 1136:276-88. doi: 10.1196/annals.1425.032.

Ray, R., P. Ong and S Jimenez. 2014. "Impacts of the Widening Divide: Los Angeles at the Forefront of the Rent Burden Crisis." Vol. Los Angeles, Ca.: Center for the Study of Inequality, UCLA Luskin School of Public Affairs,.

Repetti, Rena L, Shelley E Taylor and Teresa E Seeman. 2002. "Risky Families: Family Social Environments and the Mental and Physical Health of Offspring." *Psychological bulletin* 128(2):330.

Rey-Lopez, J. P., G. Vicente-Rodriguez, M. Biosca and L. A. Moreno. 2008. "Sedentary Behaviour and Obesity Development in Children and Adolescents." *Nutr Metab Cardiovasc Dis* 18(3):242-51. doi: 10.1016/j.numecd.2007.07.008.

Rose, D., K. O'Malley, L. F. Dunaway and J. N. Bodor. 2014. "The Influence of the Wic Food Package Changes on the Retail Food Environment in New Orleans." *J Nutr Educ Behav* 46(3 Suppl):S38-44. doi: 10.1016/j.jneb.2014.01.008.

Rossen, Lauren M and Kenneth C Schoendorf. 2012. "Measuring Health Disparities: Trends in Racial− Ethnic and Socioeconomic Disparities in Obesity among 2-to 18-Year Old Youth in the United States, 2001–2010." *Ann Epidemiol* 22(10):698-704.

Ruttle, P. L., K. N. Javaras, M. H. Klein, J. M. Armstrong, L. R. Burk and M. J. Essex. 2013. "Concurrent and Longitudinal Associations between Diurnal Cortisol and Body Mass Index across Adolescence." *J Adolesc Health* 52(6):731-7. doi: 10.1016/j.jadohealth.2012.11.013.

Scaramella, L. V., S. L. Sohr-Preston, K. L. Callahan and S. P. Mirabile. 2008. "A Test of the Family Stress Model on Toddler-Aged Children's Adjustment among Hurricane Katrina Impacted and Nonimpacted Low-Income Families." *J Clin Child Adolesc Psychol* 37(3):530-41. doi: 10.1080/15374410802148202.

Schreier, H. M. and E. Chen. 2013. "Socioeconomic Status and the Health of Youth: A Multilevel, Multidomain Approach to Conceptualizing Pathways." *Psychol Bull* 139(3):606-54. doi: 10.1037/a0029416.

Schultz, D. J., C. Byker Shanks and B. Houghtaling. 2015. "The Impact of the 2009 Special Supplemental Nutrition Program for Women, Infants, and Children Food Package Revisions on Participants: A Systematic Review." *J Acad Nutr Diet* 115(11):1832-46. doi: 10.1016/j.jand.2015.06.381.

Scott, K. A., S. J. Melhorn and R. R. Sakai. 2012. "Effects of Chronic Social Stress on Obesity." *Curr Obes Rep* 1(1):16-25. doi: 10.1007/s13679-011-0006-3.

Sekhobo, J., L. Edmunds, S.E. Whaley and M. Koleilat. 2013. "Obesity Prevalence among Low-Income, Preschool-Aged Children--New York City and Los Angeles County, 2003-2011." *MMWR Morb Mortal Wkly Rep* 62(2):17-22.

Shrewsbury, V. and J. Wardle. 2008. "Socioeconomic Status and Adiposity in Childhood: A Systematic Review of Cross-Sectional Studies 1990-2005." *Obesity (Silver Spring)* 16(2):275-84. doi: 10.1038/oby.2007.35.

Singh, Amika S, Chris Mulder, Jos WR Twisk, Willem Van Mechelen and Mai JM Chinapaw. 2008. "Tracking of Childhood Overweight into Adulthood: A Systematic Review of the Literature." *Obesity Reviews* 9(5):474-88.

Singh, G. K., M. Siahpush and M. D. Kogan. 2010a. "Neighborhood Socioeconomic Conditions, Built Environments, and Childhood Obesity." *Health Aff (Millwood)* 29(3):503-12. doi: 10.1377/hlthaff.2009.0730.

Singh, Gopal K, Mohammad Siahpush and Michael D Kogan. 2010b. "Rising Social Inequalities in Us Childhood Obesity, 2003–2007." *Ann Epidemiol* 20(1):40-52.

Skelton, Joseph A, Megan B Irby, Joseph G Grzywacz and Gary Miller. 2011. "Etiologies of Obesity in Children: Nature and Nurture." *Pediatric Clinics of North America* 58(6):1333-54.

Skinner, Jean, Betty Ruth Carruth, James Moran, Kelly Houck, James Schmidhammer, Ann Reed, Frances Coletta, Richard Cotter and Dana Ott. 1998. "Toddlers' Food

Preferences: Concordance with Family Members' Preferences." *Journal of Nutrition Education* 30(1):17-22.

Smith, Patricia K, Barry Bogin and David Bishai. 2005. "Are Time Preference and Body Mass Index Associated?: Evidence from the National Longitudinal Survey of Youth." *Economics & Human Biology* 3(2):259-70.

Sobal, Jeffery and Albert J Stunkard. 1989. "Socioeconomic Status and Obesity: A Review of the Literature." *Psychological bulletin* 105(2):260.

Sominsky, L. and S. J. Spencer. 2014. "Eating Behavior and Stress: A Pathway to Obesity." *Front Psychol* 5:434. doi: 10.3389/fpsyg.2014.00434.

Spencer, S. J. and A. Tilbrook. 2011. "The Glucocorticoid Contribution to Obesity." *Stress* 14(3):233-46. doi: 10.3109/10253890.2010.534831.

Stimson, R. H., J. Andersson, R. Andrew, D. N. Redhead, F. Karpe, P. C. Hayes, T. Olsson and B. R. Walker. 2009. "Cortisol Release from Adipose Tissue by 11beta-Hydroxysteroid Dehydrogenase Type 1 in Humans." *Diabetes* 58(1):46-53. doi: 10.2337/db08-0969.

Stomby, A., R. Andrew, B. R. Walker and T. Olsson. 2014. "Tissue-Specific Dysregulation of Cortisol Regeneration by 11betahsd1 in Obesity: Has It Promised Too Much?". *Diabetologia* 57(6):1100-10. doi: 10.1007/s00125-014-3228-6.

Strauss, R. S. and J. Knight. 1999. "Influence of the Home Environment on the Development of Obesity in Children." *Pediatrics* 103(6):e85.

Swinburn, B. and A. Shelly. 2008. "Effects of Tv Time and Other Sedentary Pursuits." *Int J Obes (Lond)* 32 Suppl 7:S132-6. doi: 10.1038/ijo.2008.249.

Swinburn, B. A., G. Sacks, K. D. Hall, K. McPherson, D. T. Finegood, M. L. Moodie and S. L. Gortmaker. 2011. "The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments." *Lancet* 378(9793):804-14. doi: 10.1016/s0140-6736(11)60813-1.

Swinburn, Boyd, Garry Egger and Fezeela Raza. 1999. "Dissecting Obesogenic Environments: The Development and Application of a Framework for Identifying and Prioritizing

Environmental Interventions for Obesity." *Preventive Medicine* 29(6):563-70. doi: http://dx.doi.org/10.1006/pmed.1999.0585.

Tanner, J.M. 1990. *Foetus into Man: Physical Growth from Conception to Maturity*. Cambridge, Massachusetts: Harvard University Press.

Tate, Eleanor B., Wendy Wood, Yue Liao and Genevieve F. Dunton. 2015. "Do Stressed Mothers Have Heavier Children?: A Meta-Analysis on the Relationship between Maternal Stress and Child Body Mass Index." *Obes Rev* 16(5):351-61. doi: 10.1111/obr.12262.

Thompson, R.A. 2014. "Stress and Child Development." *The Future of Children* 24(1):41-59.

Thomson, M., J.C. Spence, K. Raine and L. Laing. 2008. "The Association of Television Viewing with Snacking Behavior and Body Weight of Young Adults." *Am J Health Promot* 22:329–35.

Tottenham, N. 2014. "The Importance of Early Experiences for Neuro-Affective Development." *Curr Top Behav Neurosci* 16:109-29.

Trasande, L. and S. Chatterjee. 2009. "The Impact of Obesity on Health Service Utilization and Costs in Childhood." *Obesity (Silver Spring)* 17(9):1749–54.

Tsai, Alexander C. 2015. "Home Foreclosure, Health, and Mental Health: A Systematic Review of Individual, Aggregate, and Contextual Associations." *PLoS One* 10(4):e0123182. doi: 10.1371/journal.pone.0123182.

U.S. Census Bureau. 2016. "Quick Facts: Los Angeles County, California."

USDA. 2015. "Choose My Plate: Health and Nutrition Information for Preschoolers."

USDA ERS. 2012. "U.S. Household Food Security Survey Module: Six-Item Short Form." Vol.: USDA Economic Research Service.

Verhoeven, Marjolein, Marianne Junger, Chantal van Aken, Maja Deković and Marcel A. G. van Aken. 2010. "Parenting and Children's Externalizing Behavior: Bidirectionality During

Toddlerhood." *Journal of Applied Developmental Psychology* 31(1):93-105. doi: http://dx.doi.org/10.1016/j.appdev.2009.09.002.

Wang, M.C. . 2013. "Obesity and Asian-Americans: Prevalence, Risk Factors, and Future Research Directions. ." Pp. 239-50 in *Handbook of Asian American Health*. New York, NY: Springer Science + Business Media.

Wang, Y. and Q. Zhang. 2006. "Are American Children and Adolescents of Low Socioeconomic Status at Increased Risk of Obesity? Changes in the Association between Overweight and Family Income between 1971 and 2002." *Am J Clin Nutr* 84(4):707-16.

Wang, Youfa. 2001. "Cross-National Comparison of Childhood Obesity: The Epidemic and the Relationship between Obesity and Socioeconomic Status." *International Journal of Epidemiology* 30(5):1129-36. doi: 10.1093/ije/30.5.1129.

Wang, Youfa. 2011. "Disparities in Pediatric Obesity in the United States." *Advances in Nutrition: An International Review Journal* 2(1):23-31.

Webber, L., C. Hill, J. Saxton, C. H. Van Jaarsveld and J. Wardle. 2009. "Eating Behaviour and Weight in Children." *Int J Obes (Lond)* 33(1):21-8. doi: 10.1038/ijo.2008.219.

Weden, M. M., P. B. Brownell, M. S. Rendall, C. Lau, M. Fernandes and Z. Nazarov. 2013. "Parent-Reported Height and Weight as Sources of Bias in Survey Estimates of Childhood Obesity." *Am J Epidemiol* 178(3):461-73. doi: 10.1093/aje/kws477.

Weedn, A. E., J. J. Hale, D. M. Thompson and P. M. Darden. 2014. "Trends in Obesity Prevalence and Disparities among Low-Income Children in Oklahoma, 2005-2010." *Child Obes* 10(4):318-25. doi: 10.1089/chi.2014.0022.

Whaley, Shannon E., Lorrene D. Ritchie, Phil Spector and Judy Gomez. 2012. "Revised Wic Food Package Improves Diets of Wic Families." *J Nutr Educ Behav* 44(3):204-09. doi: http://dx.doi.org/10.1016/j.jneb.2011.09.011.

WHO. 2012. "Population-Based Approaches to Childhood Obesity Prevention." Vol. Geneva, Switzerland: World Health Organization.

WHO CSDH. 2008. "Closing the Gap in a Generation: Health Equity through Action on the Social Determinants of Health. Final Report of the Commission on Social Determinants of Health." Vol. Geneva: World Health Organization.

Revisions in the Wic Food Packages (2014).

Wilkinson, Richard G and Michael Gideon Marmot. 2003. *Social Determinants of Health: The Solid Facts*: World Health Organization.

Williams, C. , AZA Consulting, J. Rosen, J. Hudman, M. O'Malley and Kaiser Commission on Medicaid and the Uninsured. 2004. "Challenges and Tradeoffs in Low-Income Family Budgets: Implications for Health Coverage." Vol.

Williams, David R, Selina A Mohammed, Jacinta Leavell and Chiquita Collins. 2010. "Race, Socioeconomic Status, and Health: Complexities, Ongoing Challenges, and Research Opportunities." *Annals of the New York Academy of Sciences* 1186(1):69-101.

Williams, David R and Michelle Sternthal. 2010. "Understanding Racial-Ethnic Disparities in Health Sociological Contributions." *Journal of Health and Social Behavior* 51(1 suppl):S15-S27.

Wilson, S. M. and A. F. Sato. 2014. "Stress and Paediatric Obesity: What We Know and Where to Go." *Stress Health* 30(2):91-102. doi: 10.1002/smi.2501.

Winkleby, M. A. and C. Cubbin. 2003. "Influence of Individual and Neighbourhood Socioeconomic Status on Mortality among Black, Mexican-American, and White Women and Men in the United States." *J Epidemiol Community Health* 57(6):444-52.

Woolf, Steven H and Paula Braveman. 2011. "Where Health Disparities Begin: The Role of Social and Economic Determinants—and Why Current Policies May Make Matters Worse." *Health affairs* 30(10):1852-59.

Yongqing, G., J. Gordon and W. Sun. 2014. "Is Poverty Associated with Obesity among American Children?". *Proc Natl Acad Sci U S A* 111(22):E2237. doi: 10.1073/pnas.1405656111.

Zenk, Shannon N., Lisa M. Powell, Angela M. Odoms-Young, Ramona Krauss, Marian L. Fitzgibbon, Daniel Block and Richard T. Campbell. 2014. "Impact of the Revised Special Supplemental Nutrition Program for Women, Infants, and Children (Wic) Food Package Policy on Fruit and Vegetable Prices." *J Acad Nutr Diet* 114(2):288-96. doi: http://dx.doi.org/10.1016/j.jand.2013.08.003.

Zhang, Q. and Y. Wang. 2007. "Using Concentration Index to Study Changes in Socio-Economic Inequality of Overweight among Us Adolescents between 1971 and 2002." *Int J Epidemiol* 36(4):916-25. doi: 10.1093/ije/dym064.

Zilko, CE Margerison and C Cubbin. 2013. "Dynamic Poverty Experiences and Development of Overweight in a Prospective Cohort of Us Children Ages 4 to 14." *Obesity (Silver Spring)* 21(7):1438.