UNIVERSITY OF CALIFORNIA

Los Angeles

Multilevel Determinants of Childhood Obesity

A Dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Public Health

by

Yen-Jung Chang

2012

ABSTRACT OF THE DISSERTATION

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Doctor of Philosophy in Public Health

University of California, Los Angeles, 2012

Professor Donald E. Morisky, Chair

The prevalence of obesity among US children and adolescents has rapidly increased in the past several decades, and the epidemic of childhood obesity is currently a serious public health concern in the United States. This dissertation consists of three studies examining individual- and neighborhood-level determinants of childhood obesity. The study area was Los Angeles County in California. Our first study examined the effects of maternal employment, individual socioeconomic status (SES), and neighborhood SES on childhood obesity. The second study not only investigated the independent effect of neighborhood food environment on childhood obesity, but also examined the mediation and moderation effects of household grocery shopping distance on the relationship between neighborhood food environment and childhood obesity. The third study assessed the comparability of two commercial (i.e., InfoUSA and Dun &

Bradstreet) and one government (i.e., Los Angeles County Department of Public Health) food environment databases which can be used to measure neighborhood food environment.

Our main findings indicated that maternal part-time employment was associated with increased child's BMI, and children's TV-watching time mediated this relationship. In addition, both individual- and neighborhood-level SES measures were inversely associated with childhood obesity. We also found that children living in neighborhoods with lower density of supermarkets and grocery stores or living in neighborhoods with higher density of convenience stores were more likely to have higher BMI. Findings from our comparison study reported that for the InfoUSA vs. Dun & Bradstreet comparison, similarity of counts was high for supermarkets & grocery stores and convenience stores. For Los Angeles County Department of Public Health vs. Dun & Bradstreet comparison, similarity of counts was high for chain supermarkets, independent grocery stores, meat and fish markets, sweets stores, and bakeries; similarity was low for fast-food stores and liquor stores. Census tract characteristics (i.e., median income, percent minority) were associated with levels of similarity across databases.

This dissertation identified that maternal part-time employment, individual and neighborhood SES, and neighborhood food environment may be important determinants of childhood obesity. For the measure of neighborhood food environment, the accuracy of secondary data sources remains a considerable issue and additional validation studies are recommended.

The dissertation of Yen-Jung Chang is approved.

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2012

DEDICATION

To my parents for their unconditional love and support

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Chapter 1. Introduction

Background and Significance

The Prevalence and Trends in Childhood Obesity and Overweight in the United States

The prevalence of obesity among US children and adolescents has rapidly increased in the past several decades, and the epidemic of childhood obesity is currently a serious public health concern in the United States (Ogden et al., 2006). It is especially alarming that childhood obesity is associated with a variety of adverse physiological and psychological health outcomes, and significant health care and social costs (Vivier & Tompkins, 2009; Cawley, 2010). According to the most recent estimates from the National Health and Nutrition Examination Survey (NHANES) in 2009 and 2010, 16.9% of children and adolescents aged 2 to 19 years in the United States were obese (i.e., based on the Centers for Disease Control and Prevention (CDC) definition, at or above the 95th percentile of Body Mass Index (BMI) for age), and 31.8% were overweight or obese (i.e., at or above the 85th percentile of BMI for age) (Ogden et al., 2012; Barlow & the Expert Committee, 2007). Data from the NHANES indicate that about 14.4% of boys and 9.6% of girls aged 2-5 are obese. Among children aged 6-11, about 20.1% of boys and 15.7% of girls are obese. For adolescents from 12 to 19 years old, the obesity rate reaches 19.6% among male and 17.1% among female adolescents (Ogden et al., 2012).

While the obesity epidemic affects all racial/ethnic groups in the US, the ethnic minority populations such as Latino and African Americans are disproportionally affected. In 2009-2010, the rates of obesity among children and adolescents aged 2-19 were 21.2% for Mexican Americans and 24.3% for non-Hispanic Blacks, compared to 14.0% of non-Hispanic Whites (Ogden et al., 2012).

The increase in childhood obesity in the US has been on the rise since 1976-1980. Between the two NHANES surveys conducted in 1976-1980, and 2009-2010, the prevalence of obesity among children aged 2-5 doubled from 5.0% to 12.1%. Among children aged 6-11, obesity has almost tripled during the same time period from 6.5% to 18.0%. The prevalence of obesity also tripled among adolescents aged 12-19, rising from 5.0% to 18.4% (Ogden *et al.*, 2006; Ogden *et al.*, 2012). Even though scholars have advised that the epidemic of childhood obesity is a serious public health concern and implemented abundant interventions to combat childhood obesity, the prevalence of childhood obesity remains nowadays.

Health Consequences and Social Costs of Childhood Obesity

Serious concerns regarding the epidemic of childhood obesity have been raised due to its various adverse health outcomes. Childhood overweight and obesity are associated with increased health risks for many diseases, such as cardiovascular diseases, type 2 diabetes, hypertension, and orthopedic complications in children and adolescents (Vivier & Tompkins, 2009; Reilly *et al.*, 2003; Dietz, 1998). The data from the Bogalusa Heart study indicated the increased odds ratios for atherosclerotic lesions and hypertension in overweight children (Freedman *et al.*, 1999). In addition to cardiovascular risks, increasing childhood obesity prevalence is associated with the increase in the prevalence of insulin resistance and type 2 diabetes (Dietz, 1998; Sinha & Kling, 2009; Vivier & Tompkins, 2009). Other common comorbidities include orthopedic complications and breathing disorders including asthma and obstructive sleep apnea (Vivier & Tompkins, 2009).

Psychosocial impacts of childhood obesity include stigmatization, lower self-esteem, and poorer quality of life (Schwimmer, Burwinkle, & Varni, 2003; Vivier & Tompkins, 2009).

Scholars have concluded that obese children are more likely to experience psychological or psychiatric problems compared to non-obese children (Reilly *et al.*, 2003). Meanwhile, obese children may show poorer school performance, which potentially has resulted from absenteeism due to obesity-related health problems (Datar, Sturm & Magnabosco, 2004).

In addition, overweight children are at risk for obesity into adulthood. Obese adolescents have approximately 75% chance of becoming obese adults, even after adjusting for parental weight status (Whitaker *at al.*, 1997). A longitudinal analysis using national data also indicated the dramatic increase in obesity prevalence from adolescence into adulthood. In the study cohort, it is alarming that 90% of obese adolescents remained obese into their 30s. The study concluded that obesity prevalence doubled from adolescence to the early 20s, and the prevalence doubled again from the early 20s to late 20s or early 30s, with strong tracking from adolescence into adulthood (Gordon-Larsen, The, & Adair, 2010).

In adults, obesity is associated with various health risks as well. It has been found that obesity is associated with adult morbidities, including diabetes, coronary heart disease, atherosclerosis, and hip fracture (Reilly *et al.*, 2003; Biro & Wien, 2010). In addition to the risks of morbidities, obese adults also experience a greater risk of mortality (Solomon & Manson, 1997). According to a recent study analyzing causes of death reported in 2000, obesity was associated with about 112,000 excess deaths in the U.S. (Flegal, Graubard, Williamson, & Gail, 2005). Scholars also found that obesity markedly decreased life expectancy, and could even possibly reverse the positive life expectancy trends that have been achieved through the control of infectious diseases and reduction of smoking (Stewart, Cutler, & Rosen, 2009). A study which analyzed the causes of death indicated that obesity accounts for 400,000 deaths per year, second only to tobacco (Mokdad, Marks, Stroup, & Gerberding, 2004).

Beyond those individual health consequences, the increasing prevalence of obesity also has substantial effects on the health care system and society. Scholars have observed the increasing prevalence of obesity and estimated future prevalence using national survey data. Wang *et al.* (2008) proposed that 51.1% adults will be obese, and 86.3% will be either overweight or obese by 2030. Among children and adolescents, if current trends continue, the prevalence of childhood obesity will be about 30% by 2030 (Wang *et al.*, 2008). In terms of the estimated health-care costs, childhood obesity accounts for $14 billion annually (Cawley, 2010). The costs are more significant among obese adults. The health costs of overweight and obesity in adults could have been as much as $78.5 billion in 1998, and the expenditures accounted for 9.1% of total annual US medical expenditures. Approximately half of this total was financed by Medicare and Medicaid (Finkelstein, Fiebelkorn, & Wang, 2003). Recently, scholars presented updated estimates and revealed that the annual medical spending attributable to obesity has increased to be $147 billion in 2008 (Finkelstein, Trogdon, Cohen & Dietz, 2009). Moreover, Wang *et al.* (2008) estimated that total health-care costs attributable to obesity or overweight would double every decade to $956 billion US dollars by 2030, accounting for 18% of total US health-care costs.

The Causes of Childhood Obesity Epidemic in the United States

The primary cause of increased body weight is the imbalance of energy intake and expenditure, which means that individuals gain weight when the calories consumed exceed the energy expended. There are various individual, familial, social, economic, and environmental factors associated with the increase in energy intake and the reduction of energy expenditure. Any of those factors which can alter energy balance of the human body, even with small effects, will lead to obesity in the long term (Ebbeling, Pawlak, & Ludwig, 2002; Wieting, 2008; Sinha & Kling, 2009; French, Story, & Jeffery, 2001). Socio-economic development and changes in people's lifestyles and environments have all contributed to the obesity epidemic nowadays. During the past few decades, the prevalence of childhood obesity has been increasing in almost all industrialized countries or regions including North America and some countries in Europe (Wang & Lobstein, 2006).

Genetic influences underlying obesity such like parental obesity are significant predictors of a child's obesity (Whitaker *et al.*, 1997). Individual lifestyles including diet habits and physical activity are strongly associated with weight status as well. Although poor dietary habits and sedentary lifestyle have been viewed as the proximal causes of childhood obesity, environmental factors can also alter individual behaviors concerning diet and physical activity, and contribute to the increase in childhood obesity in a fundamental way (Goodman, 2009; Wieting, 2008; French, Story, & Jeffery, 2001). Different levels of determinants and theories contributing to child's dietary intake and weight gain are discussed in the following section.

Parental Influences on Childhood Obesity

Discussing the determinants of childhood obesity, scholars have pointed out the importance of parental influences on child's diet and weight. The association between parental factors and childhood obesity is likely due to the influences of shared genes and family environment (Whitaker *et al.*, 1997; Agras, Lawrence, Fiona, & Helena, 2004). From the developmental systems perspective, in addition to genetic influences, the eating environment, including food availability and child-feeding practices, is associated with learned food preferences and food selection patterns (Birch, 1999). Birch *et al.* (1998) proposed that children's eating behaviors and food preferences are shaped by the availability and accessibility of foods at home, by modeling parents' eating habits, and by child-feeding practices. Empirical studies have also reported that the availability of fruits and vegetables in the home is a strong predictor of the intake of fruits and vegetables among adolescents (Neumark-Sztainer, Wall, Percy, & Story, 2003). Additionally, the consumption of both healthy foods and soda drinks in children and adolescents is related to their parents' consumption (Diamant, Babey, Jones, & Brown, 2009). Implied by the theory of parental influences on child's eating behaviors and the empirical evidence, the mother or childcare provider acts as a role model and gatekeeper to determine the foods purchased, prepared, and provided for the child.

Scholars have also documented the influences of family structure on child's diet, sedentary behaviors such as television viewing, and BMI, based on the assumption that poor family functioning is associated with inadequate parental supervision and regulation of children's eating and activity behaviors (Gabel & Lutz, 2000; Bagley, Salmon, & Crawford, 2006; Gibson *et al.*, 2007; Jingxiong *et al.*, 2007). Children living in single parent families more frequently consume prepared foods and are more likely to be obese compared to children from couple parent families (Gabel & Lutz, 2000). Additionally, family size is inversely associated with child's obesity rate. One empirical study compared obesity risk and family size and found that adolescents from one-child families were at the higher risk of being obese (Ravelli & Belmont, 1979). It was also reported that the number of siblings in the family is inversely related to child's obesity status measured by triceps skinfold thickness (Rona & Chinn, 1982).

Maternal Employment and Childhood Obesity

Over the past several decades, one important factor related to the change in family life is the increase in labor force participation of mothers. Accompanying the secular increase in childhood obesity rate, the labor force participation rate for mothers with children under 18 has risen from 47% in 1975 to 71% in 2011 in the United States (Department of Labor, Bureau of Labor Statistics, 2012). The social, economic, demographic, and normative shifts during the past decades have contributed to the increased trends and acceptance of women working for pay (Sayer, 2005). Mothers have been viewed as default family food managers who hold the main responsibility for meal preparation and they spend twice as much time as fathers in family food preparation (Blake *et al.*, 2009; Schafer & Schafer, 1989). With the increases in women's labor force participation, women's time allocations have also changed by reducing the time spent in unpaid household work (Sayer, 2005). Among employed mothers, the work and family demands have influenced how they manage household tasks including family food choices (Blake *et al.*, 2009).

Recently, scholars have documented the positive relationship between maternal employment and childhood obesity using empirical data (Anderson, Butcher, & Levine, 2003; Cawley & Liu, 2007; Fertig, Glomm, & Tchernis, 2009; Brown *et al.*, 2010). There are several potential explanations for this relationship. The supervision hypothesis proposes that maternal employment may contribute to childhood obesity through maternal supervision and nutrition provision in the family (Fertig, Glomm, & Tchernis, 2009). Scholars have used economic theories to explain the connection: mothers who participate in the labor force may have less time to prepare meals, and some may have less time and energy available to supervise and participate in children's activities (Fertig, Glomm, & Tchernis, 2009). According to the theory of household production and the theory of the allocation of time, the combination of time and market goods is required to produce commodities for the household to utilize, including food production. Due to mothers' budget and time constraints, the influences of maternal employment on childhood obesity result from the tradeoff between time and money. For employed mothers, the increase in earnings leads to the decision of substituting money for time in food production at home, thereby increasing the consumption of food away-from-home (Gronau, 1977; Ben-Shalom, 2010). Studies have documented the association between consumption of food away-from-home and childhood obesity (Thompson *et al.*, 2004; Taveras *et al.*, 2005). Such food tends to have higher levels of fat and saturated fat and lower levels of dietary fiber than food prepared at home (Guthrie, Lin, & Prazao, 2002).

Based on this theoretical concept, research has focused on employed mothers' allocation of time to household work related to children's diet and physical activity. Gordon *et al.* (2007) suggested that the increasing time that mothers spend in the labor force reduces the amount of time spent in child care, resulting in higher rates of childhood intestinal problems. Other scholars also reported that employed mothers spend less time cooking and are more likely to purchase processed foods for their children, which results in negative influences on children's diet quality (Cawley & Liu, 2007).

Although previous studies found the positive relationship between maternal employment and childhood obesity, the mechanisms are complex and many factors may affect this relationship. For example, the assistances of child care outside the home have been highlighted in childhood obesity prevention in the United States (Centers for Disease Control and Prevention Division of Physical Activity, Nutrition and Obesity, 2012). Although employed mothers have less time to supervise children's diet and physical activity, their children can still obtain appropriate nutrition and participate in physical activity if they stay in child care settings. Child care outside the home may be a setting which provides not only healthy meals but also the opportunity of physical activity for children (Kaphingst & Story, 2009; Centers for Disease Control and Prevention Division of Physical Activity, Nutrition and Obesity, 2012).

Socioeconomic Status and Childhood Obesity

Another factor which may affect the relationship between maternal employment and childhood obesity is household income. On one hand, employed mothers' contributions to household income enable the purchase of more healthy foods. On the other hand, the maternal supervision hypothesis suggests that mothers' employment may increase the consumption of food away from home, which makes children vulnerable to obesity (Fertig, Glomm, & Tchernis, 2009). In the existing literature, some scholars have indicated that the positive association between maternal employment and childhood obesity exists only in households with higher socioeconomic status (SES), while other studies have reported that the association appears in non-affluent households as well when mothers work long hours (Anderson, Butcher, & Levine, 2003; Chia, 2008; Brown *et al.*, 2010).

In general, empirical studies have concluded that US children from lower SES backgrounds are more likely to be overweight, compared to their moderate and high SES counterparts (Wang & Kumanyika, 2007a; Wang & Beydoun, 2007b; Delva, O'Malley, & Johnston, 2006). Scholars have developed hypotheses regarding the pathways between socioeconomic determinants and health outcomes. Link and Phelan (1995) proposed that social factors such as socioeconomic status are the fundamental causes of disease, because people with higher socioeconomic status have better access to important resources including knowledge, money, prestige, and social connections; thus, they are able to avoid risk of disease and have better health outcomes. The disadvantaged SES may also influence dietary choice. Previous studies suggested that due to the inverse association between energy density of foods and energy cost, attempting to reduce diet costs may lead to the selection of energy-dense foods, increase in energy intake, and risk of obesity (Drewnowski, 2004). Since employed mothers who encounter time constraints to prepare foods at home often choose to have meals away from home, they are possible to buy more energy-dense foods because of limited income. Considering the inverse association between SES and childhood obesity prevalence, the theory that social factors fundamentally influence health, and the theory of substituting money for time in family food production, the effects of SES on the relationship between maternal employment and childhood obesity are complex and in need of clarification using empirical data.

Neighborhood SES, Neighborhood Food Environment, and Childhood Obesity

Previous studies inspecting the connection between maternal employment and childhood obesity have focused on the mother's time allocation and household income. However, in addition to individual and social determinants, scholars suggested the environmental contributions to the obesity epidemic (Hill & Peters, 1998; Booth, Pinkston, & Poston 2005; Papas *et al.*, 2007; Holsten, 2009). The obesogenic environments induce changes in energy balance and lead to the increased risk of obesity. From the economic viewpoint, over the past several decades, technological advancements (e.g., the development of mechanical equipments) have helped people to be increasingly productive at work and at home while expending fewer calories. Moreover, the development of food technology has also contributed to the increase in caloric consumption through improvements in the availability of and accessibility to food

(Finkelstein, Ruhm & Kosa, 2005; Gorin & Grane, 2009). Although healthy behaviors like eating low energy-dense foods and having regular physical activity are significant protectors against obesity, it is difficult to adopt and maintain these behaviors in the obesogenic environments which do not support them (Hill & Peters, 1998).

The neighborhood effects on health outcomes and the possible causal mechanisms have been documented. Reviewing the literature, Ellen *et al.* (2001) concluded that neighborhoods affect health through various mechanisms: neighborhood institutions and resources (e.g., neighborhood food environment), stressors in the physical and social environments, and neighborhood-based networks and norms. Supporting the theory of neighborhood effects on health and the notion of obesogenic environments, there has been empirical evidence indicated that neighborhood food environment characteristics, such as accessibility to fresh fruits and vegetables, are important predictors of the intake of healthy foods and of decreased risk of obesity. Scholars also have reported that neighborhood-level characteristics were associated with neighborhood food environment. People living in disadvantaged neighborhoods such as low-income urban areas have less access to supermarkets, consume fewer fruits and vegetables, and have higher body mass index (Diez-Roux *et al.*, 1999; Morland, Wing, & Diez-Roux, 2002; Powell *et al.*, 2007). However, there has been also evidence showing no association between neighborhood food environment and obesity (Burdette & Whitaker, 2004; Simmons *et al.*, 2005; Sturm & Datar, 2005; Jeffery *et al.*, 2006). The inconsistent findings of existing studies were possibly because that the mechanisms are complex and the environmental effects can be moderated or mediated by a number of factors including personal characteristics, food purchase and eating behaviors, and psychosocial factors (Glanz *et al.*, 2005). In addition, the limitations of cross-sectional study design and the lack of valid and reliable measures of food environment may influence results interpretation (Glanz *et al.*, 2005; Mckinnon *et al.*, 2009).

In measuring food environments, researchers have typically adopted data from three types of sources: proprietary commercial sources (i.e., InfoUSA, Dun & Bradstreet), governmental sources (i.e., agricultural department), and non-proprietary commercial sources (i.e., Yellow Pages). Although using these secondary databases may have advantages of time- and labor-saving, it was criticized that there may be problems with regard to accuracy of these secondary data sources (Kowaleski-Jones *et al.*, 2009).

As we discussed above, since both individual and environmental factors influence behaviors including diet and physical activity, it is important to consider the effects of multiple levels of determinants on childhood obesity. Adopting Giddens' structuration theory (Giddens, 1984) which describes that social practice is the constitution of both social structure and agency, we proposed that social structural conditions, such as social and environmental resources, interact with people's behaviors and both social structure and individual behaviors influence health outcomes. Therefore, we examined social structural conditions including social and physical environments and their associations with people's eating behaviors and weight status. This dissertation consists of three studies examining individual- and neighborhood-level determinants of childhood obesity. In the first study, the effects of maternal employment, individual SES, and neighborhood SES on childhood obesity were all examined. The second study not only investigated the independent effect of neighborhood food environment on childhood obesity, but also examined the mediation and moderation effects of household grocery shopping distance. The third study investigated the comparability of three different secondary data sources which can be used to measure neighborhood food environment. The research aims and questions of three studies will be summarized in the following section. In the chapters that follow, we will discuss findings regarding the specific aims of three studies.

Research Aims

Drawing from concepts of the ecological model that human behaviors were influenced by not only the social and physical environments where they reside but also personal characteristics, the overall objective of this dissertation is to investigate multilevel factors of child's weight status, including maternal employment, individual and neighborhood SES, neighborhood food environment, and grocery shopping distance. In addition, this dissertation also aims to improve the availability of database which measures neighborhood food environment for future research by investigating the comparability of secondary food listing databases from a variety of resources.

Study 1: Maternal employment, individual and neighborhood SES, and childhood obesity

The objective of the first study is to investigate the cross-sectional associations between maternal employment, individual and neighborhood SES, and childhood obesity among households in Los Angeles County using secondary data.

Study 2: Neighborhood food environment, grocery shopping distance, and childhood obesity

The second study aims to examine the cross-sectional associations between neighborhood food environment, household's grocery shopping distance, and childhood obesity among households in Los Angeles County using secondary data.

Study 3: Assessing the comparability of neighborhood food environment data from government and commercial sources

The third study is a comparison study which aims to assess the comparability of neighborhood food environment data from governmental and commercial data sources by comparing the agreement of food store counts estimated by each database. Our second objective is to explore the census tract characteristics among census tracts with low level of agreement in food store counts obtained from different data sources.

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Chapter 2

Maternal Employment, Individual and Neighborhood SES, and Childhood Obesity

Introduction

The Significance of Childhood Obesity in the United States

The prevalence of obesity among US children and adolescents has rapidly increased in the past several decades, and the epidemic of childhood obesity is currently a serious public health concern in the United States. According to the most recent estimates from the National Health and Nutrition Examination Survey (NHANES) in 2009 and 2010, 16.9% of children and adolescents aged 2 to 19 years in the United States were obese (i.e., based on the Centers for Disease Control and Prevention (CDC) definition, at or above the 95th percentile of Body Mass Index (BMI) for age), and 31.8% were overweight or obese (i.e., at or above the 85th percentile of BMI for age) (Ogden *et al.*, 2012; Barlow & the Expert Committee, 2007).

Serious concerns regarding the epidemic of childhood obesity have been raised due to its various adverse physiological and psychological health outcomes, and significant health care and social costs (Vivier & Tompkins, 2009; Cawley, 2010). Childhood overweight and obesity are associated with increased health risks for many diseases, such as cardiovascular diseases, type 2 diabetes, hypertension, and orthopedic complications in children and adolescents (Vivier & Tompkins, 2009; Reilly *et al.*, 2003; Dietz, 1998). In addition, overweight children are at risk for obesity into adulthood. Obese adolescents have approximately 75% chance of becoming obese adults, even after adjusting for parental weight status (Whitaker *at al.*, 1997). In adults, obesity is associated with increased health risks and greater risk of mortality (Solomon & Manson, 1997;

Reilly *et al.*, 2003; Biro & Wien, 2010). Beyond those individual health consequences, the increasing prevalence of obesity also has substantial effects on the health care system and the society. It was predicted that the prevalence of childhood obesity will be about 30% by 2030 (Wang *et al.*, 2008). In terms of the estimated health-care costs, childhood obesity accounts for $14 billion annually (Cawley, 2010).

The primary cause of increased body weight is the imbalance of energy intake and expenditure, which means that individuals gain weight when the calories consumed exceed the energy expended. There are various individual, familial, social, economic, and environmental factors associated with the increase in energy intake and the reduction of energy expenditure. Any of those factors which can alter energy balance of the human body, even with small effects, will lead to obesity in the long term (Ebbeling, Pawlak, & Ludwig, 2002; Wieting, 2008; Sinha & Kling, 2009; French, Story, & Jeffery, 2001).

Maternal Employment and Childhood Obesity

Over the past several decades, one important factor related to the change in family life is the increase in labor force participation of mothers. Accompanying the secular increase in childhood obesity rate, the labor force participation rate for mothers with children under 18 has risen from 47% in 1975 to 71% in 2010 in the United States (Department of Labor, Bureau of Labor Statistics, 2012). Recently, scholars have documented the positive relationship between maternal employment and childhood obesity using empirical data (Anderson, Butcher, & Levine, 2003; Cawley & Liu, 2007; Fertig, Glomm, & Tchernis, 2009; Brown *et al.*, 2010).

Scholars have suggested that maternal supervision on child’s diet and physical activity may be the mediators of this relationship. The supervision hypothesis proposes that mothers who participate in the labor force may have less time to prepare meals, and some may have less time and energy available to supervise and participate in children's activities (Fertig, Glomm, & Tchernis, 2009). Based on this theoretical concept, research has focused on employed mothers' allocation of time to household work related to children's diet and physical activity. Gordon *et al.* (2007) suggested that the increasing time that mothers spend in the labor force reduces the amount of time spent in child care, resulting in increased childhood intestinal problems. Other studies also reported that employed mothers spend less time cooking, have decreased frequency of family meals, and are more likely to purchase processed foods for their children, which results in negative influences on children's diet quality (Cawley & Liu, 2007; Neumark-Sztainer *et al.*, 2003). Moreover, the lack of supervision on children's activities may lead to the increase in children's sedentary behaviors, such as TV-watching. Behaviors related to TV-watching are also risk factors of childhood obesity. Children spending significant time in watching television will not only engage in less physical activity, but also will be exposed to a great quantity of food advertisements, and tend to have more snacks or sugary beverages during watching television (Caroli, Argentieri, Caardone & Masi, 2004; Crespo et al., 2001).

Socioeconomic Status and Childhood Obesity

The inverse association between socioeconomic status (SES) and childhood obesity prevalence has been well documented (Wang & Kumanyika, 2007a; Wang & Beydoun, 2007b; Delva, O'Malley, & Johnston, 2006). SES is a multidimensional concept, which can be measured by the combination of income, education, and occupation. A standardized composite SES index has been developed and commonly applied in research on health behaviors and various health outcomes (Green, 1970). Link and Phelan (1995) proposed that social factors such as socioeconomic status are the fundamental causes of disease, because people with higher socioeconomic status have better access to important resources including knowledge, money, prestige, and social connections; thus, they are able to avoid risk of disease and have better health outcomes.

In addition to acting as a fundamental cause, individual level SES may modify the relationship between maternal employment and childhood obesity. On one hand, employed mothers' contributions to household income enable the purchase of more healthy foods. On the other hand, the maternal supervision hypothesis suggests that mothers' employment may increase the consumption of food away from home, which makes children vulnerable to the risk of obesity (Fertig, Glomm, & Tchernis, 2009). In the existing literature, some scholars have indicated that the positive association between maternal employment and childhood obesity exists only in households with higher SES, while other studies have reported that the association appears in non-affluent households as well when mothers work long hours (Anderson, Butcher, & Levine, 2003; Chia, 2008; Brown *et al.*, 2010). The findings to date regarding the effects of individual level SES on the relationship between maternal employment and childhood obesity remain diverse and need further clarification using empirical data.

Neighborhood Level Factors and Childhood Obesity

Recently, scholars have also investigated the neighborhood effects on childhood obesity and the possible causal mechanisms. Neighborhood level determinants including the accessibility to healthy food, physical environment for physical activity, and neighborhood SES, have been proposed as explanations for the obesity epidemic (Black & Macinko, 2008). These determinants are related to each other; for example, neighborhood SES was associated with access to food and other resources related to health outcomes. Empirical evidence has reported that people living in disadvantaged neighborhoods such as low-income urban areas have less access to supermarkets, consume fewer fruits and vegetables, and have higher body mass index (Diez-Roux *et al.*, 1999; Morland, Wing, & Diez-Roux, 2002; Powell *et al.*, 2007).

This cross-sectional study primarily aims to investigate the relationship between maternal employment and childhood obesity among households in Los Angeles County. We also plan to verify whether individual SES interacts with maternal employment and influences childhood obesity. Moreover, drawing from concepts of the ecological model, the study takes into account multilevel covariates and simultaneously examines the effects of individual and neighborhood SES on childhood obesity. Since the maternal supervision hypothesis suggests that maternal employment affects childhood obesity through the supervision on child's diet and physical activity, we also examine whether children's meal and sedentary activity habits mediate the association between maternal employment and childhood obesity. Our specific aims were as follows:

Specific Aim 1: Examine the independent association between children's BMI and maternal employment, individual-level SES, and neighborhood-level SES in a cross-sectional analysis of our study sample of children in Los Angeles County.

Specific Aim 2: Investigate whether individual SES moderates the relationship between maternal employment and children's BMI.

Specific Aim 3: Investigate whether children's meal and sedentary activity habits mediate the relationship between maternal employment and children's BMI.

The research questions pertinent to our study aims are as follows:

1) What are the independent associations between children's BMI and maternal employment, individual-level SES, and neighborhood-level SES?

2) Does individual SES moderate the relationship between maternal employment and children's BMI?

3) Do children's meal and sedentary activity habits mediate the relationship between maternal employment and children's BMI?

Methods

Data and Study Sample

This study used data from the Los Angeles Family and Neighborhood Survey (L.A. FANS), a longitudinal study of a stratified random sample of 65 neighborhoods (25 non-poor, 20 poor, and 20 very poor) in Los Angeles County. The L.A. FANS Wave 1, which was conducted in 2000-2001, was designed to explore how neighborhoods affect both children's development and health among children and adults by conducting household interviews which investigated demographics, family income, employment, perceptions of the neighborhood, health status, and other characteristics among sampled children and adults (Sastry, Ghosh-Dastidar, Adams, & Pebley, 2006). Since this study acquired information on neighborhood-level characteristics among study subjects, the application for access to L.A. FANS Restricted Data Version 2 was submitted and approved by the RAND and the institutional review boards at the University of California, Los Angeles.

The L.A. FANS data collected information from sampled children aged 9 to 17 (n=1,454), but only children aged 12 to 17 who provided height and weight information (n=809) were included in the study. Among these 809 children, 754 children could be linked with their female primary care givers (PCGs) who had information required by this study (e.g., employment status and demographics). Primary care givers are household members who are responsible for the sampled children, and they are usually mothers (Sastry, Ghosh-Dastidar, Adams, & Pebley, 2006). After applying a random selection procedure, we selected one child in each household and eventually the study sample included 637 children from 65 census tracts. The complete data flow was demonstrated in Figure 1.

Measures

Individual-Level Variables

The key outcome variable is the indicator of childhood obesity, which is measured by Body Mass Index (BMI), the most widely used tool for assessing childhood obesity. Body Mass Index (weight (kg) divided by the square of height (m^2)) is the standard measurement used to assess a child or adolescent's weight status (Cole *et al.*, 2005; Barlow & the Expert Committee, 2007). In order to compare children of various ages and genders, BMI can be converted into a BMI *z*-score adjusted for age and sex using the Centers for Disease Control and Prevention's 2000 growth reference (Kuczmarski *et al.*, 2002). The sex- and age-specific CDC BMI growth charts define "overweight" for children and adolescents aged 2 to 20 years as BMI ≥ 95^{th} percentile and "at-risk-of-overweight" as BMI ≥ 85^{th} percentile to < 95^{th} percentile (Kuczmarski *et al.*, 2002). This study used self-reported height and weight measurements for children aged 12 to 17 in the L.A.FANS to calculate BMI and the corresponding BMI *z*-score, and then determined their weight categories according to the CDC cut-offs. In this study, childhood obesity will be assessed using continuous BMI *z*-score and categorical variable, obese (BMI ≥ 95th percentile), overweight (BMI ≥ 85^{th} percentile to < 95^{th} percentile), and normal weight (BMI< 85^{th} percentile).

Maternal employment status was determined by asking whether female primary care givers are currently working and, if so, the average number of working hours per week. Categorical employment status (i.e., unemployed, full-time employed, and part-time employed) and continuous measure (i.e., number of working hours per week) were used in the analysis. Individual SES was measured using the two-factor SES index, which was constructed by scoring years of education and household income (Green, 1970). Household income was the annual income of family members from wages, salaries, commissions and tips earned during the preceding calendar year. In the L.A. FANS income data, family members included the respondent, his/her spouse/partner, and children of the respondent and spouse/partner who lived in the household.

Other covariates included child's immigration status, female primary care giver's age and race/ethnicity, the number of children in the family, couple or single parent family, and maternal BMI. Maternal BMI was calculated using female primary care giver's self-reported height and weight. The frequency of having a family dinner per week and the hours of a child's TV-watching were also accounted for in this study.

Neighborhood-Level Variable

The neighborhood SES index was constructed using five census tract variables: education (percentage of persons 25 years and older without a high school degree), income (median family income), wealth (median home value), occupational status (percentage of blue collar workers), and employment (percentage unemployed) (Winkleby & Cubbin, 2003; Brown, Vargas, Ang, & Pebley, 2008). These five census tract variables were obtained from the 2000 U.S. Census files.

Statistical Analysis

Data were analyzed using SAS version 9.1.3 (SAS Institute Inc., Cary, NC, USA, 2008). Multivariate multilevel linear regression models were conducted using SAS PROC MIXED procedure to examine the associations between childhood obesity and the following covariates: maternal employment, individual SES, neighborhood SES, maternal age, race/ethnicity, BMI, child's immigration status, couple or single parent family, and the number of children in the family. All continuous variables used in the multilevel modeling analyses were first centered to the grand mean of each variable to facilitate the interpretation of the intercept. The significant P-value was set at 0.05 or less.

Results

Sample Description

Among these 637 children, half (51%) were male; their mean age was 14.5 years. More than half (57.1%) were Hispanic, one-quarter were white (25%), and around one-tenth were African-American (10.4%). The majority of them (77.7%) were born in the United States. In each household, the child's data were linked to his/her female primary care giver's survey record. The mean age of matched female primary care givers was 42.2; more than half (64%) completed high school or higher education level; and most (67.2%) were currently married. The frequency distribution of race/ethnicity of female primary care givers was similar to the race/ethnicity distribution of the children.

Among 637 households, the mean annual household income was $57,713 and on average there were 2.4 children in a household. According to the sampling design of L.A. FANS, these 637 households were selected from 65 sampling census tracts grouped by poverty level. Twenty census tracts were very poor (tracts in the top 10 percent of the poverty distribution), 20 were poor (tracts in the 60-89th percentiles), and 25 were not poor (tracts in the bottom 60 percent of the distribution).

Maternal Employment Status

We applied three approaches to capture the employment information of PCGs: current employment status, current work hours per week, and the employment status in the past two years. More than one-third of PCGs were not employed when they participated in the survey; 15.7% had part-time jobs; and 48% had full-time jobs. The average work hours of employed

PCGs was 36.8 hours per week. In terms of PCGs' employment history, 26.4% of PCGs have never been employed in the previous two years.

Maternal Obesity

PCGs also reported their heights and weights, which were used to calculate BMI and determine obesity status. Their mean BMI was 26.5; 41% had normal weight, 33% were overweight, and 24.8% were obese.

Childhood Obesity

Children's obesity status was determined by their BMI z-scores adjusted for age and sex using the CDC's 2000 growth reference. In this study, the children's mean BMI z-score was 0.45 with standard deviation of 1.04; 64.4% of children were of normal weight, 19.6% were overweight, and 16% were obese.

Bivariate Analyses Examining Associations between Children's BMI z-scores and Covariates of Interest

More children with employed PCGs were obese compared to children with unemployed PCGs (17.2% versus 13.9%), and more children with part-time employed PCGs were obese compared to children with full-time employed PCGs (21% versus 16%). However, the Chi-square tests revealed that these differences were not statistically significant. Additionally, on average, children with part-time employed PCGs had higher BMI z-scores than the other two groups of children (0.71 versus 0.56 and 0.53), but there was no significant difference indicated by ANOVA test.

Considering PCGs' employment history in the previous two years, among children with PCGs who have been employed during that period, 16.4% were obese, while among children with PCGs who have not been employed in that period, 14.9% were obese. Similarly, the difference was not statistically significant.

Additionally, children having higher BMI z-scores were more likely to be Hispanic or African-American ($p=0.003$), were more likely to be U.S.-born children ($p=0.005$), had higher maternal levels of BMI ($p<0.001$), had lower maternal levels of education ($p=0.005$), had lower household levels of income ($p<0.046$), and lived in neighborhoods with lower SES ($P<0.001$), compared to those having lower BMI z-scores.

Multilevel Regression Models of Children's BMI

Table 3 shows the results of multilevel multivariate regression models of children's BMI z-scores among only 630 children because seven children whose races were classified as "other" were excluded from the analyses. Model A tested PCGs' employment status and individual SES, and it indicated that both PCGs' employment status and individual SES were significant predictors of childhood obesity, after controlling for covariates including the PCG's age, BMI, race, child's immigration status, and family structure. Model B tested the interaction between PCGs' employment status and individual SES index; however, there was no significant interaction effect observed, and adding the interaction term did not improve the model fit. In Model C, we dropped the previous interaction effect and added a neighborhood-level factor, neighborhood SES index. Results showed that neighborhood SES performed as a significant predictor of childhood obesity ($\beta=-0.01$; $p<0.05$); the effect of PCGs' employment status disappeared, and the effect of individual SES decreased. Moreover, including neighborhood SES index in multilevel multivariate regression models improved the model fit.

Child's Meal and Sedentary Activity Habits

On average, children in the study had dinner with family 4.5 days per week and they spent 2.5 hours and 3.5 hours watching TV per weekday and weekend day, respectively. Employed PCGs and their children reported a lower frequency of family meals compared to unemployed families ($p<0.05$), but the frequency of family meals was not different among groups of children with different weight statuses. In terms of a child's TV-watching hours during weekdays, children with part-time employed PCGs spent less time watching TV than their counterparts, but the differences were not statistically significant according to the ANOVA test. Nevertheless, obese children spent more time watching TV compared to overweight or normal weight children ($p<0.05$).

Table 5 presents multilevel models of children's BMI z-scores predicted by the child's TV-watching hours, in addition to all the covariates tested in our prior analyses. Results revealed that neither PCGs' employment status nor children's TV-watching hours was associated with children's BMI z-scores. The effect of maternal employment disappeared after we added a child's TV-watching hours in the regression model (presented in Model A). Individual SES was negatively associated with childhood obesity in Model A (β=-0.02; $p<0.05$), but its effect disappeared after including the neighborhood SES index in Model B. Model B indicated that significant predictors of childhood obesity included neighborhood SES, maternal obesity status, and child's immigration status ($p<0.05$).

Discussion

This study examined different levels of factors contributing to childhood obesity and indicated that neighborhood SES more significantly predicted childhood obesity than individual SES, maternal employment, and child's sedentary behavior. While several studies proposed the influences of maternal employment and individual SES on the risk of childhood obesity, our findings emphasized the significance of neighborhood context.

In our analyses, we found the significant effect of maternal part-time employment on a child's BMI increase when we fitted the regression model controlling for individual SES. Holding a part-time job is associated with the increased risk of childhood obesity. This may be because part-time employed mothers may not have a fixed or regular work schedule and the nonstandard work schedules may interfere with the mothers' time spent in important family routines, including meal preparation and supervision of a child's sedentary activity. Compared to unemployed mothers, those part-time employed mothers in our study were more likely to be non-Hispanic white, reported higher family incomes, and had higher education levels. Compared to mothers employed full-time, part-time employed mothers reported similar education levels, but lower family incomes. To date, only a few studies have examined the association between maternal nonstandard work schedules and childhood obesity. Our findings were similar to the work published by Miller and Han (2008); however, there was empirical evidence which did not support this association (Morrissey *et al.*, 2011). Since literature remains insufficient to reach a consensus on this topic, we suggest future research should further investigate the differences in effects of maternal standard versus nonstandard work schedules on childhood obesity and inspect potential mechanisms.

Interestingly, we found that the effect of maternal employment on a child's BMI disappeared after we adjusted for both individual and neighborhood SES in a multilevel regression model. To our knowledge, few previous studies which aim to examine the relationship between maternal and childhood obesity accounted for the influences of neighborhood SES. Our findings revealed that neighborhood SES should not be omitted and accounting for this factor may contribute new information to research concerning maternal employment and childhood obesity.

Although some previous studies indicated that the positive association between maternal employment and childhood obesity was stronger among wealthier households or children with higher maternal education levels, we found no discrepancy in the effect of maternal employment between households with different SES levels. Using a composite measure of individual SES, we observed no interaction effects between individual SES index and maternal employment. We also tested the modification effects of single SES indicators, maternal education levels, and household income, but no interaction effect of single indicators was identified in our results.

In the past, simultaneous examination of both individual- and neighborhood-level SES determinants of childhood obesity using a multilevel analysis has rarely been performed. Meanwhile, since most studies to date have used only a single SES indicator and comparatively few studies have used neighborhood-level SES, it was recommended to use composite measures of SES and incorporate SES indicators measured at both the household and neighborhood levels (Shrewsbury & Wardle, 2008). Our findings used composite measures of individual- and neighborhood-level SES, and we found that both individual- and neighborhood-level SES measures were inversely related to childhood obesity, which was consistent with findings of previous studies (Janssen *et al.*, 2006; Shrewsbury and Wardle, 2008). The economic and social resources relating to behaviors may partially explain the inverse associations. According to the theoretical framework proposed by Sobal (1991), indicators of individual SES contribute to obesity via different ways: education influences knowledge and beliefs, and income influences access to resources. In terms of neighborhood-level SES, it has also been interpreted by the access to resources which influence diet and exercise. Neighborhood features contributed to the development of obesity through constraining a healthy diet due to the limited accessibility to healthy foods and discouraging physical activity owning to limited green space and safety concerns (Black & Macinko, 2008).

In contrast to the results concluded by previous review studies (Janssen *et al.*, 2006), we found that the individual-level SES was a weaker predictor of childhood obesity compared to the neighborhood-level SES. Our findings highlighted the importance of obesogenic environment which induces changes in energy balance and contributes to the increased risk of obesity. Even though people's individual social and economic resources are capable of promoting healthy behaviors such as eating low energy-dense foods and having regular physical activity, it is difficult to adopt and maintain these healthy behaviors in the obesogenic environment (Hill & Peters, 1998).

We also investigated the effects of a child's meal and sedentary activity habits on childhood obesity. Although children with employed PCGs were more likely to have meals with family members, we found no association between the frequency of family meals and a child's BMI. To the contrary, children's TV-watching hours were associated with children's BMI but not associated with PCGs' employment status. Comparing the Model A in table 3 and Model A in table 5, results revealed that children's TV-watching hours mediated the association between maternal part-time employment and children's BMI when we did not account for the effects of neighborhood SES. Although children's TV-watching time was not significantly associated with children's BMI in the multivariate regression model, the finding regarding its mediation effect partially supported the maternal supervision hypothesis proposed by previous studies (Fertig, Glomm, & Tchernis, 2009). Furthermore, we did not test the mediation effect of the frequency of family meals because the association between family meal frequency and children's BMI was not observed in our prior analysis.

This study used BMI as the measurement and indicator of childhood obesity. However, we acknowledge that BMI has several limitations in determining obesity. First, BMI is a surrogate assessment rather than a direct measure of body fat. Moreover, BMI, like body weight itself, reflects both the weight of lean tissue and the weight of fat tissue (Garn, Leonard, & Hawthorne, 1986). Another concern with the accuracy of BMI is the bias of self-reported height and weight. A study compared self-reported height and weight for L.A. FANS sample of children with measured height and weight, and reported the underestimates of overweight and obesity among adolescents based on self-reported information. The self-reported height and weight underestimated adolescent obesity by almost 35% overall (Buttenheim *et al.*, 2011).

In addition to the limitations of BMI, the cross-sectional study design limits causal inferences between childhood obesity and all the covariates of interest. The neighborhood selection bias should also be considered in this multilevel study and finding interpretations. Moreover, although child care outside the home is considered as a factor which may intervene childhood obesity among households with employed mothers (Kaphingst & Story, 2009; Centers for Disease Control and Prevention Division of Physical Activity, Nutrition and Obesity 2012), this information was not available in our study. Finally, the neighborhood-level SES measures used in this study were obtained from census data which were the aggregated individual-level variables. We suggest that further multilevel studies measure neighborhood SES by incorporating additional neighborhood-level variables, such as building environment (e.g., land use, density of food outlets, and green spaces), and examine the associations between childhood obesity and more extensive measure of neighborhood SES.

In conclusion, neighborhood SES was more significantly associated with the risk of childhood obesity compared to individual SES, maternal employment, and a child's sedentary behavior. This study contributed to our knowledge and understanding of multilevel determinants of childhood obesity by using composite measures of individual- and neighborhood-level SES to investigate the influences of multilevel socioeconomic factors simultaneously. Our results found that both individual- and neighborhood-level SES indices were inversely related to childhood obesity; thus, health interventions should target both levels of determinants to promote healthy diet and physical activity among children. Since our findings indicated that maternal employment may affect children's sedentary behaviors and the risk of obesity, encouraging physical activity at school and educating children to limit TV-watching time are also recommended.

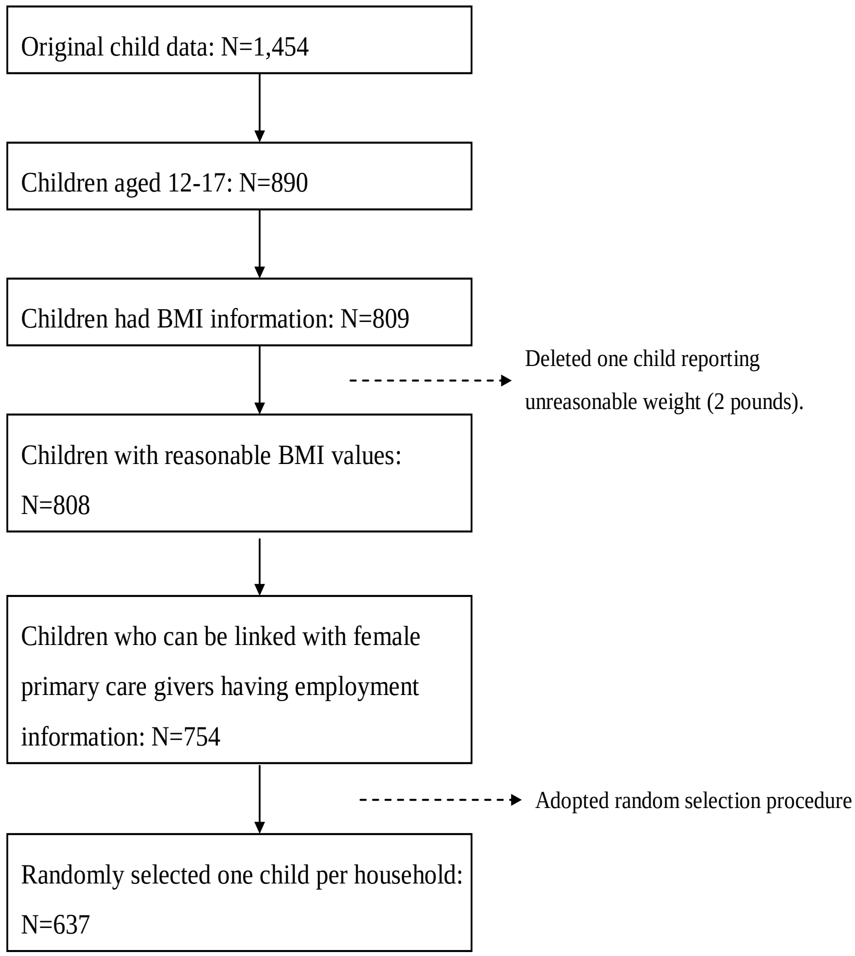

Figure 1. Selection of study subjects obtained from the L.A. FANS wave 1 data

Table 1. Characteristics of sample (n= 637)

	% Mean (SD)
<u>Sample of Children</u>	
Gender	
Male	51.0
Female	49.0
Age	14.5 (1.6)
Race	
Hispanic	57.1
Non-Hispanic White	25.0
African American	10.4
Asian	6.4
Other	1.1
Immigration Status	
1st generation in U.S.	22.3
2nd generation in U.S.	38.1
3rd generation in U.S.	39.6
BMI z-score	0.45 (1.04)
Obesity Status [a]	
Obese	16.0
Overweight	19.6
Normal	64.4
<u>Sample of Female Primary Care Givers</u>	
Age	42.2 (7.4)
Race	
Hispanic	54.0
Non-Hispanic White	27.5
African American	10.4
Asian	7.1
Other	1.1
Education level	
< High school	36.0
≥High school/GED	64.0

Table 1. (continued)

	% Mean (SD)
Marital status	
Currently married	67.2
Currently not married	32.8
Employment status	
Currently working: full-time	48.0
Currently working: part-time	15.7
Currently not working	36.3
Current work hours per week (among those employed)	36.8 (12.1)
Maternal BMI	26.5 (4.7)
<u>Household characteristics</u>	
Household income	57,713.2 (70,302.8)
Number of children in household	2.4 (1.3)

[a] Child's obesity was defined as BMI $\geqq 95^{th}$ percentile; overweight was defined as BMI $\geqq 85^{th}$ percentile to $< 95^{th}$ percentile.

Table 2. Children's weight status, by primary care giver's (PCG's) employment status, individual SES, and neighborhood SES (n= 637)

	Children's weight Status, %			Children's BMI z-score, mean (SD)
PCG's employment status	Obese	Overweight	Normal	
currently working full-time	16.0	19.9	64.1	0.56 (1.02)
currently working part-time	21.0	19.0	60.0	0.71 (1.04)
currently not working	13.9	19.5	66.7	0.53 (1.04)
Individual SES **				
High	16.3	14.2	69.5	0.46 (1.03)
Low	15.8	24.3	59.9	0.67 (1.03)
Neighborhood SES ***				
High	10.2	15.9	74.0	0.35(1.01)
Low	21.5	23.8	54.7	0.79 (1.01)

* p<.05; ** p<.01; *** p<.001

Table 3. Multilevel regression models of children's BMI z-scores

Children's BMI z-scores (n=630)	Model A β	Model B β	Model C β
PCG's employment status			
employed full-time (versus unemployed)	0.14	0.13	0.12
employed part-time (versus unemployed)	0.26*	0.24	0.24
Individual SES index [a] (centered)	-0.02***	-0.02	-0.01*
Interaction: individual SES * full-time employed (versus individual SES * unemployed)		-0.01	
Interaction: Individual SES * part-time employed (versus individual SES * unemployed)		-0.01	
Neighborhood SES index [b] (centered)			-0.04 *
PCG's age (centered)	-0.01	-0.01	-0.01
PCG's Race			
Hispanic (versus White)	-0.002	0.001	-0.11
African American (versus White)	-0.14	-0.13	-0.25
Asian (versus White)	0.19	0.21	0.16
Maternal BMI (centered)	0.06 ***	0.06 ***	0.05 ***
U.S. born child (yes versus no)	0.31 **	0.31 ***	0.32 **
Live with spouse/partner (yes versus no)	0.12	0.12	0.11
Number of children in household (centered)	-0.05	-0.05	-0.06
Intercept	0.07	0.09	0.16
AIC	1568.3	1582.7	1547.2

* p<.05; ** p<.01; *** p<.001

[a]: The individual socioeconomic status index was constructed using individual education level and family income

[b]: The neighborhood socioeconomic status index was constructed using five census tract variables: education (percentage persons 25 years and older without a high school degree), income (median family income), wealth (median home value), occupational status (percentage blue collar workers), and employment (percentage unemployed).

Table 4. Children's meal and sedentary activity habits (n= 637)

	Mean (SD)
Family meal and sedentary activities	
Days of family meal per week	4.5 (2.3)
Hours of child's TV-watching per weekday	2.5 (2.5)
Days of family meal per week, by maternal employment status *	
Currently working: full-time	4.3 (2.3)
Currently working: part-time	4.6 (2.3)
Currently not working	4.8 (2.3)
Days of family meal per week, by children's weight status [a]	
Obesity	4.4 (2.3)
Overweight	4.7 (2.4)
Normal	4.5 (2.3)
Hours of child's TV-watching per weekday, by maternal employment status	
Currently working: full-time	2.5 (2.2)
Currently working: part-time	2.0 (1.3)
Currently not working	2.8 (3.2)
Hours of child's TV-watching per weekday, by children's weight status [a] *	
Obesity	3.5 (4.5)
Overweight	2.4 (2.0)
Normal	2.3 (1.7)

* p<.05

[a] Child's obesity was defined as BMI $\geqq 95^{th}$ percentile; overweight was defined as BMI $\geqq 85^{th}$ percentile to $< 95^{th}$ percentile.

Table 5. Multilevel regression models of children's BMI z-scores, including children's TV-watching hours

	Model A	Model B
Child's BMI z-score (n=630)	β	β
PCG's employment status		
employed full-time (versus unemployed)	-0.09	-0.12
employed part-time (versus unemployed)	0.16	0.12
Child's TV-watching hours per weekday (centered)	0.04	0.03
Individual SES index [a] (centered)	-0.02 *	-0.01
Neighborhood SES index [b] (centered)		-0.06 **
PCG's age (centered)	-0.01	-0.01
PCG's Race		
Hispanic (versus White)	-0.06	-0.24
African American (versus White)	-0.28	-0.49*
Asian and others (versus White)	0.38	0.29
Maternal BMI (centered)	0.04 **	0.03 *
U.S. born child (yes versus no)	0.42 **	0.40 *
Live with spouse/partner (yes versus no)	0.004	0.002
Number of children in household (centered)	-0.004	-0.02
Intercept	0.14	0.35
AIC	696.4	687.8

* p<.05; ** p<.01; *** p<.001

[a]: The individual socioeconomic status index was constructed using individual education level and family income

[b]: The neighborhood socioeconomic status index was constructed using five census tract variables: education (percentage persons 25 years and older without a high school degree), income (median family income), wealth (median home value), occupational status (percentage blue collar workers), and employment (percentage unemployed).

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Chapter 3

Neighborhood Food Environment, Grocery Shopping Distance, and Childhood Obesity

Introduction

Significance of Childhood Obesity in the United States

The rapid development of the epidemic of childhood obesity is currently a serious public health concern in the United States (Ogden *et al.*, 2006). According to the most recent estimates from the National Health and Nutrition Examination Survey (NHANES) in 2009 and 2010, 16.9% of children and adolescents aged 2 to 19 years in the United States were obese (i.e., based on the Centers for Disease Control and Prevention (CDC) definition, at or above the 95th percentile of Body Mass Index (BMI) for age), and 31.8% were overweight or obese (i.e., at or above the 85th percentile of BMI for age) (Ogden *et al.*, 2012; Barlow & the Expert Committee, 2007). Scholars also predicted that if current trends continue, the prevalence of childhood obesity will be about 30% by 2030 (Wang *et al.*, 2008). It is especially alarming that childhood obesity is associated with a variety of adverse physiological and psychological health outcomes (Vivier & Tompkins, 2009; Cawley, 2010). Beyond those individual health consequences, the increasing prevalence of obesity also has substantial effects on the healthcare system and the society. It was estimated that childhood obesity accounts for $14 billion healthcare costs annually (Cawley, 2010).

Neighborhood Food Environment and Childhood Obesity

In addition to various individual and social determinants of obesity, scholars have suggested possible environmental contributions to the obesity epidemic (Hill & Peters, 1998; Finkelstein, Ruhm, & Kosa, 2005; Gorin & Grane, 2009). Although healthy behaviors, like eating low energy-dense foods and having regular physical activity, are significant protectors against obesity, it is difficult for people to adopt and maintain these behaviors in the obesogenic environments which induce changes in energy balance and lead to the increased risk of obesity (Hill & Peters, 1998).

Recently, there have been studies examining the influence of build environment (e.g., food environment) on obesity. Food environment involves not only the sources of energy and nutrients, but also the circumstances surrounding the obtainment and consumption of energy and nutrients (Holsten, 2009). According to the definition proposed by Glanz *et al.* (2005), the concept of neighborhood food environment consists of the type, location, and accessibility of food outlets in a defined location; therefore, researchers can measure neighborhood food environment by observing the distribution of food outlets. There has been empirical evidence reporting that neighborhood food environment characteristics, such as accessibility to fresh fruits and vegetables, are important predictors of the intake of healthy foods and increases in BMI. People living in disadvantaged neighborhoods, such as low-income urban areas, have less access to supermarkets, consume fewer fruits and vegetables, and have higher BMI (Diez-Roux *et al.*, 1999; Morland, Wing, & Diez-Roux, 2002; Powell *et al.*, 2007). However, there has been also evidence showing no association between neighborhood food environment and obesity (Burdette & Whitaker, 2004; Simmons *et al.*, 2005; Sturm & Datar, 2005; Jeffery *et al.*, 2006). These inconsistent findings were possibly because that the mechanisms are complex and the environmental effects can be moderated or mediated by a number of factors including personal characteristics, food purchase and eating behaviors, and psychosocial factors (Glanz *et al.*, 2005). Individual food purchase behavior, for instance, can act as either a potential mediator or a moderator; however, there has been insufficient evidence proving both its mediation and moderation effects on the connection between food environment and obesity. A previous study has suggested that food shopping distance should be taken into consideration when researchers investigate the association between neighborhood socioeconomic status (SES) and adulthood obesity (Inagami *et al.*, 2006). The influences of food shopping distance on obesity are complex, as it may be associated with the eating patterns and may subsequently influence weight status. For example, people traveling farther for food purchase tended to purchase greater amounts of food, and this purchase pattern was associated with increased risk of obesity (Chandon & Wansink, 2002). Therefore, in addition to testing the independent effect of neighborhood food environment on childhood obesity, we hypothesized that grocery shopping distances may mediate or moderate the association between neighborhood food environment and childhood obesity. Accounting for the influences of food shopping habits may improve our understanding of current controversial associations between neighborhood food environment and obesity.

Furthermore, another possible explanation of the existing inconsistent findings regarding the associations between neighborhood food environment and obesity is the lack of a comprehensive measure of accessibility to food. The measure of food access should consider not only the location of food outlets and distance traveled, but also access to appropriate transportation for food shopping (Sparks, Bania, & Leete, 2009). Therefore, this study also accounted for household car ownership in addition to other covariates including sociodemographics, family structure, household SES, and neighborhood SES. Our specific aims were as follows:

Specific Aim 1: Assess the independent association between neighborhood food environment and childhood obesity in a cross-sectional analysis of a sample of households in Los Angeles County.

Specific Aim 2: Examine whether household grocery shopping distance mediates or moderates the association between neighborhood food environment and childhood obesity in our study sample of children. The mediation effect and the moderation effect of household grocery shopping distance will be tested respectively.

The research questions pertinent to our study aims are as follows:

1) What is the association between the neighborhood food environment and childhood obesity in Los Angeles households? Which characteristics of neighborhood food environment are associated with increased risk of childhood obesity?

2) Is the association between neighborhood food environment and childhood obesity mediated by household grocery shopping distance?

3) Is the association between neighborhood food environment and childhood obesity moderated by household grocery shopping distance?

Methods

Study sample

This study used the data from the Los Angeles Family and Neighborhood Survey (L.A. FANS) Wave 1 which was conducted in 2000-2001. L.A. FANS was designed to explore how neighborhoods affect children's development and health among children and adults by conducting household interviews that investigated demographics, family income, employment, perceptions of the neighborhood, health status, and other characteristics among sampled children and adults (Sastry, Ghosh-Dastidar, Adams, & Pebley, 2006). This study used L.A. FANS Restricted Data Version 2, which is the middle level of restricted data that adds actual census tract number and enables researchers to link neighborhood characteristics with individual and household data in L.A.FANS. The restricted data use application was approved by RAND and the institutional review boards at the University of California, Los Angeles. As we mentioned in the first study, we randomly selected 637 households with adults and children who provided information required by this study (e.g., BMI, employment status, distance of grocery shopping, and demographics).

The neighborhood food environment data were from the American Business Information (ABI) database, produced commercially by InfoUSA, and provided information on grocery stores in each census track in Los Angeles County in 2000. The InfoUSA database source was primarily mined from Yellow Page directories published each year by Regional Bell Operating Companies and independent phone companies, and also compiled records from various input data sources, such as Business White Pages, Federal, State, and Municipal government Blue Pages, annual reports, and industrial and regional business journals. The InfoUSA database categorized stores using the six-digit InfoUSA-defined Standard Industrial Classification (SIC) codes: the first four digits are standard as defined by the U.S. Department of Labor; the last two digits are InfoUSA-defined subcategories, which provide added resolution to the standard SIC codes.

Measures

Dependent Variables

The key outcome variable was the indicator of childhood obesity, which is measured by BMI, the most widely used tool for assessing childhood obesity. The concept of BMI is to assess body weight adjusted for height. In general, BMI (weight (kg) divided by the square of height (m^2)) is the standard measurement used to assess child or adolescent weight status (Cole *et al.*, 2005; Barlow & the Expert Committee, 2007). BMI was converted into a BMI *z*-score adjusted for age and sex using the CDC's 2000 growth reference (Kuczmarski *et al.*, 2002). In this study, childhood obesity was assessed using a continuous BMI *z*-score, which was calculated by self-reported height and weight measures for children aged 12 to 17 years in the L.A. FANS Wave 1.

Neighborhood-Level Variables

The neighborhood food environment was defined by the number of each type of store per square mile in the census tract. In the InfoUSA database, grocery stores (i.e., SIC 4-digit code is 5411) were categorized as follows: the combined category of supermarkets and grocery stores, and convenience stores. We combined supermarkets and grocery stores in our analyses, as these two types of stores could not be classified separately in InfoUSA. Moreover, both supermarkets and grocery stores may provide more healthy food choices, while convenience stores usually offer limited access to healthy food.

To assess neighborhood socioeconomic status, we used a composite SES index, which was also applied in our previous study using L.A. FANS data. The neighborhood SES index was constructed using five census tract variables obtained from the 2000 U.S. Census: education (percentage persons 25 years and older without a high school degree), income (median family income), wealth (median home value), occupational status (percentage blue collar workers), and employment (percentage unemployed) (Winkleby & Cubbin, 2003; Brown, Vargas, Ang, & Pebley, 2008).

Grocery Shopping Distance

Sampled adults were interviewed to provide information on the location where household members bought groceries most frequently, and L.A. FANS has released the distance between residence and the location of primary grocery store rather than the true location where subjects shopped for groceries. The distance was analyzed as a dichotomous variable: traveling within 1 mile for grocery shopping versus traveling 1 mile or more for grocery shopping.

Control Variables

In addition to the dependent and independent variables listed above, control variables included characteristics of children, adults, and households. Household characteristics included children’s immigrant status, the number of children in the family, dual- or single-parent family, car ownership, and individual SES. Individual SES was measured using the two-factor SES index, which was constructed by scoring household income and the years of education of child’s female primary caregiver (Green, 1970). Household income was the annual income of family members from wages, salaries, commissions and tips earned during the preceding calendar year. Individual-level characteristics included child's gender, age, race/ethnicity, and maternal employment status. Maternal BMI, which was calculated by the child's primary caregiver's self-reported height and weight, was also considered in the analysis.

Statistical Analysis

Data were analyzed using SAS version 9.1.3 (SAS Institute Inc., Cary, NC, USA) and multivariate multilevel linear regression models were conducted using SAS PROC MIXED to estimate the associations between childhood obesity and covariates of interest. The mediation and moderation effects of household grocery shopping distance were tested separately. Multivariate, multilevel logistic modeling procedure (SAS PORC GLIMMIX) was utilized to examine the associations between grocery shopping distance and neighborhood food environment as well as other covariates. The significant P-value was set at 0.05 or less.

Results

Sample Description

The study sample included 637 households residing in 65 census tracts in Los Angeles County. These 65 census tracts were categorized into three types: 20 were very poor (tracts in the top 10% of the poverty distribution), 20 were poor (tracts in the 60-89th percentiles), and 25 were not poor (tracts in the bottom 60% of the distribution). Among the 637 households, 82.3% owned one or more than one car; the mean annual household income was $57,713.

The study included 637 children aged 12-17 years, with mean age of 14.5 years; half (51%) were male. More than half (57.1%) were Hispanic, one-quarter were White (25%), and around one-tenth were African American (10.4%). The majority (77.7%) were born in the United States. Children's mean BMI z-score was 0.45, with a standard deviation of 1.04; 64.4% of children were within normal weight, 19.6% were overweight, and 16% were obese (Table 1). Children from households with low or median family income had higher BMI z-scores compared to children from households with high family income (0.63 and 0.64 versus 0.38; p<.05). Children living in poor and very poor neighborhoods had higher BMI z-scores compared to children living in not poor neighborhoods (0.74 and 0.79 versus 0.32; p<.001) (Table 3).

Neighborhood Food Environment

In the not-poor census tracts, supermarkets and grocery stores comprised 74%, and convenience stores 26% of all grocery stores. In the poor census tracts, supermarkets and grocery stores compromised a lower proportion of stores, and convenience stores compromised a higher proportion of stores. Meanwhile, the average number of supermarkets and grocery stores was largest in the very-poor census tracts. The average number of convenience stores was highest in the poor census tracts. However, these differences were not statistically significant (Table 2).

Results of bivariate analyses indicated that children living in neighborhoods with higher density of supermarkets and grocery stores had slightly but not significantly lower BMI z-scores compared to those living in neighborhoods with lower density of supermarkets and grocery stores (0.51 versus 0.61). Children living in neighborhoods with higher density of convenience stores had slightly but not significantly higher BMI z-scores compared to their counterparts (0.69 versus 0.52) (Table 3).

Grocery Shopping Distance

L.A. FANS released the distance of grocery shopping for each household: 48.2% of the sampled households in this study shopped for groceries within the distance of 1 mile; 51.8% traveled more than 1 mile for grocery shopping. Bivariate analysis showed that children's BMI z-scores didn't differ between households travelling for longer versus shorter distance for grocery shopping (Table 3).

Multilevel Multivariate Regression Models of Children's BMI z-scores

Table 4 showed multilevel multivariate regression models of the children's BMI z-scores. In Model A, the density of supermarkets and grocery stores was associated with decreased children's BMI z-scores; while the density of convenience stores was associated with increased children's BMI z-scores. Other significant predictors of increased children's BMI z-scores included lower neighborhood SES, higher maternal BMI, and child's U.S.-born immigrant status.

Testing Mediation Effect of Grocery Shopping Distance

Results of Model B in Table 4 showed that household grocery shopping distance was not independently associated with children's BMI z-scores. Meanwhile, adding grocery shopping distance in the regression model (Model B) didn't diminish the effects of neighborhood food environment on children's BMI z-scores. In addition, we fitted the multilevel multivariate logistic regression model of household grocery shopping distance to observe the association between neighborhood food environment and grocery shopping distance. Results shown in Table 5 indicated that neighborhood food environment was not associated with household grocery shopping distance. According to the findings presented above, we rejected our research hypothesis that grocery shopping distance mediates the association between neighborhood food environment and childhood obesity.

Testing Moderation Effect of Grocery Shopping Distance

Model C in Table 4 tested the moderation effect of grocery shopping distance by examining interactions between the measures of neighborhood food environment and household grocery shopping distance, but the results showed no interaction effects between the measures of neighborhood food environment and household grocery shopping distance. Therefore, we rejected our research hypothesis that household grocery shopping distance moderates the association between neighborhood food environment and childhood obesity.

Discussion

This study investigated the associations between childhood obesity and multilevel determinants, including neighborhood food environment, grocery shopping distance, and neighborhood characteristics. After adjusting for multilevel covariates, we confirmed our hypotheses that children living in neighborhoods with a higher density of supermarkets and grocery stores, or living in neighborhoods with a lower density of convenience stores, were more likely to have higher BMI. In general, the findings supported the previous evidence that accessibility to healthy food was a predictor of decreased risk of obesity (Diez-Roux *et al.*, 1999; Morland, Wing, & Diez-Roux, 2002; Powell *et al.*, 2007).

We hypothesized that the relationship between neighborhood food environment and childhood obesity can be mediated or moderated by household grocery shopping distance; thus, we conducted separate analysis approaches to examine the mediation effect and moderation effect of household grocery shopping distance, respectively. However, neither mediation effect nor moderation effect was identified in our findings. Future studies should continue to investigate other possible factors which either mediate or moderate the association between neighborhood food environment and childhood obesity.

In addition, grocery shopping distance has no independent effect on childhood obesity in our findings, while a previous study reported that obese adults were more likely to travel farther for grocery shopping (Inagami *et al.*, 2006). Possibly, that previous study didn't account for the effects of neighborhood food environment; or perhaps the grocery shopping habit of the child's primary caregiver was not so influential to the child's diet and BMI change. We confirmed this proposed explanation by assessing the associations between adult BMI and the same set of covariates used in our study. The results of our additional analysis indicated that after controlling for neighborhood food environment and other multilevel covariates, adults who traveled farther for grocery shopping were more likely to have higher BMIs (data not presented), which was still consistent with findings in the study conducted by Inagami and colleagues (2006). In sum, grocery shopping distance was associated with the BMI of adults but not of children, which needs more investigation in future search.

Although the logistic regression model reported no association between neighborhood food environment and grocery shopping distance, it indicated that car ownership was a significant predictor of the longer grocery shopping distance (odds ratio = 1.82, $p<0.05$), after controlling for household- and neighborhood-level covariates. Households owning cars were more likely to travel farther for grocery shopping. Neither neighborhood food environment nor neighborhood SES was associated with residents' grocery shopping distance. This may imply that people's food shopping habits were principally determined by direct access to transportation and not shaped by neighborhood characteristics, including neighborhood SES and accessibility to food outlets. Additionally, in previous literature, access to a car was identified as a predictor of BMI increase because it resulted in decreased physical activity (Frank, Andresen, & Schmid, 2004). Linking our results with previous findings, future research should note that car ownership was not only associated with decreased energy expenditure but also influential to patterns of food shopping and even consumption.

Meanwhile, our findings showed that both neighborhood-level determinants (i.e., density of grocery stores and neighborhood SES) were associated with children's BMI, while all the household-level predictors, including grocery shopping distance, car ownership, and family income, were not related to children's BMI. Although these household-level determinants were suggested as independent predictors of BMI change by previous studies, their influences were negligible in this study, which accounted for multilevel determinants. We conclude that the neighborhood-level characteristics require more inquiry in future research on the obesity problem, and those neighborhood factors should not be ignored in interventions targeting obesity prevention. Our findings support policies addressing the changes in obesogenic environments, such as improving the accessibility to food stores that provide healthy foods rather than energy-dense foods. Moreover, we suggest health education with regard to improving people's nutrition knowledge and encouraging healthy dietary intake.

We acknowledge several limitations of this study. First, BMI has its limitations in determining obesity because it reflects both the weight of lean tissue and the weight of fat tissue (Garn, Leonard, & Hawthorne, 1986); however, it remains a commonly used tool for assessing childhood obesity. Moreover, the L.A. FANS data did not provide the measured height and weight information, and the underestimates of overweight and obesity based on self-reported height and weight should be considered (Yun *et al.*, 2006). A recent study using the second wave of L.A. FANS data reported that self-reported height and weight underestimated adolescent obesity by 35% overall (Buttenheim *et al.*, 2011).

Second, the accessibility to food outlets in a neighborhood does not represent actual food consumption, and the L.A. FANS data lack direct information regarding the content and frequency of the children's food consumption. Therefore, we were unable to verify whether neighborhood food environment influences a child's weight status through the direct changes in a child's dietary intake. Third, the true location of the primary grocery stores where respondents shopped was unknown in our data; hence, we could only use a dichotomous variable in the analyses. In addition, we used store density as a proxy measure of food access, rather than measuring the frequency and amount of food purchase and consumption. The potential accuracy concern when using secondary data source to measure neighborhood food environment is also a possible limitation. Finally, neighborhood selection bias should also be considered and the causality between childhood obesity and household- and neighborhood- level covariates was unable to be identified in this cross-sectional study.

Table 1. Demographic characteristics of sample (n= 637)

	% Mean (SD)
Children characteristics	
Gender	
Male	51.0
Female	49.0
Age	14.5 (1.6)
Race	
Hispanic	57.1
Non-Hispanic White	25.0
African American	10.4
Asian	6.4
Other	1.1
Immigration Status	
1st generation in U.S.	22.3
2nd generation in U.S.	38.1
3rd generation in U.S.	39.6
Household characteristics	
Household income ($)	57,713 (70,303)
Own a car	82.3
Distance of grocery shopping	
Within 1 mile	48.2
1 mile or more	51.8
Number of children in household	2.4 (1.3)

Table 2. Census tract food environment description (n= 65)

	Poverty level of census tract [a]		
	Very poor (N=20)	Poor (N=20)	Not-poor (N=25)
Store type, %			
Supermarkets and grocery stores [b]	85.2	69.2	74.2
Convenience Stores [c]	14.8	30.8	25.8
Number of stores (SD)			
Supermarkets and grocery stores [b]	1.15 (2.16)	0.90 (1.68)	0.88 (1.20)
Convenience Stores [c]	0.20 (0.41)	0.40 (0.60)	0.32 (0.63)

*: $p<.05$

[a]: The very poor census tracts were tracts in the top 10% of the poverty distribution; poor tracts were in the 60-89th percentiles; and not-poor tracts were in the bottom 60% of the distribution.

[b]: The combined category of supermarkets and grocery stores refer to food stores with InfoUSA-defined six-digit SIC codes 541101 (food markets) and 541105 (retail grocery store).

[c]: The category of convenience stores refer to food stores with InfoUSA-defined six-digit SIC codes 541103 (convenience stores).

Table 3. Bivariate analyses examining associations between children's BMI z-scores and covariates of interest (n= 637)

	children's BMI z-scores
	Mean (SD)
Density of supermarkets and grocery stores in neighborhood [a]	
High	0.51 (1.01)
Low	0.61 (1.06)
Density of convenience stores in neighborhood [a]	
High	0.69 (0.97)
Low	0.52 (1.05)
Household grocery shopping distance	
Under 1 mile	0.59 (1.00)
1 mile or more	0.60 (1.06)
Household income [b] *	
High	0.38 (0.97)
Median	0.64 (0.99)
Low	0.63 (1.15)
Neighborhood poverty level [c] ***	
Not poor	0.32 (1.01)
Poor	0.74 (0.97)
Very poor	0.79 (1.05)

* p<.05; ** p<.01; *** p<.001

[a]: High density was the top 50% of the distribution; low density was in the bottom 50% of the distribution.

[b]: High household income was the top 25% of the distribution; median household income was in the 25-74th percentiles; and low household income was in the bottom 25% of the distribution.

[c]: The very poor census tracts were tracts in the top 10% of the poverty distribution; poor tracts were in the 60-89th percentiles; and not-poor tracts were in the bottom 60% of the distribution.

Table 4. Multilevel regression models [a] of children's BMI z-scores

Children's BMI z-scores	Model A β	Model B β	Model C β
Density of stores in tract (centered)			
Supermarkets and grocery stores	-0.02 *	-0.03 *	-0.01
Convenience stores	0.10 **	0.10 **	0.15
Grocery shopping distance (long versus short) [b]		0.05	0.11
Interaction: density of supermarkets and grocery stores*long grocery shopping distance [c]			-0.02
Interaction: density of convenience stores*long grocery shopping distance [d]			-0.04
Individual SES index [e] (centered)	-0.005	-0.003	-0.004
Neighborhood SES index [f] (centered)	-0.05 ***	-0.05 **	-0.05 **
AIC	1445.1	1356.5	1364.6

* p<.05; ** p<.01; *** p<.001

[a]: Models controlled for PCG's age, race, employment, BMI, child's gender, age, immigration status, single/dual-parents family, car ownership, and number of children in household.

[b]: Long grocery shopping distance refers to travelling for 1 mile or more; short distance refers to within 1 mile.

[c]: Interaction: density of supermarkets and grocery stores*long grocery shopping distance (versus density*short grocery shopping distance)

[d]: Interaction: density of convenience stores*long grocery shopping distance (versus density*short grocery shopping distance)

[e]: The individual SES index was constructed using family income and education level of child's primary caregiver.

[f]: The neighborhood SES index was constructed using five census tract variables: education (percentage persons 25 years and older without a high school degree), income (median family income), wealth (median home value), occupation (percentage blue collar workers), and employment (percentage unemployed).

Table 5. Multilevel logistic regression model [a] of household grocery shopping distance

Grocery shopping distance (modeling the probability of longer distance) [b]	Odds ratio
Density of stores in census tract	
Supermarkets and grocery stores	0.92
Convenience stores	0.88
Car ownership (yes versus no)	1.92 *
Individual SES index [c]	1.02
Neighborhood SES index [d]	1.04

* $p<.05$

[a]: Models controlled for PCG's age, race, employment, BMI, child's gender, age, immigration status, single/dual-parents family, and number of children in household.

[b]: Grocery shopping distance is a dichotomous variable: 0=travel within 1 mile; 1=travel 1 mile or more.

[c]: The individual SES index was constructed using family income and education level of child's primary caregiver.

[d]: The neighborhood socioeconomic status index was constructed using five census tract variables: education (percentage persons 25 years and older without a high school degree), income (median family income), wealth (median home value), occupational status (percentage blue collar workers), and employment (percentage unemployed).

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Chapter 4

Assessing the Comparability of Neighborhood Food Environment Data Obtained from Government and Commercial Sources

Introduction

Food Environment and Obesity

In addition to individual and social determinants of obesity, scholars suggested that environmental factors have contributed to the obesity epidemic (Hill & Peters, 1998; Finkelstein, Ruhm, & Kosa, 2005; Gorin & Grane, 2009). Neighborhoods affect people's health through various mechanisms: neighborhood institutions and resources (e.g., neighborhood food environment), stressors in the physical and social environments, and neighborhood-based networks and norms (Ellen *et al.,* 2001). In recent decades, research on food environment has been increased considerably and it is considered as a possible determinant of obesity epidemic (McKinnon *et al.*, 2009). Empirical evidence has indicated that accessibility to healthy foods is an important predictor of the intake of healthy food and of decreased risk of obesity. Residences living in neighborhoods with limited accessibility to healthy food were more likely to consume fewer fruits and vegetables and have a higher risk of obesity (Diez-Roux *et al.*, 1999; Morland, Wing, & Diez-Roux, 2002; Powell *et al.*, 2007). Food environment involves not only the sources of energy and nutrients, but also the circumstances surrounding the obtainment and consumption of energy and nutrients (Holsten, 2009). The broad concept of food environment includes various levels: home and media/information in addition to neighborhood food environment, the focus of this study. According to the definition proposed by Glanz *et al.* (2005), the concept of neighborhood food environment consists of the type, location, and accessibility of food outlets in a location; thus, researchers can observe the distribution of food outlets to measure neighborhood food environments.

Measure of Neighborhood Food Environment

In general, there are two common ways to study neighborhood effects on health: direct observations of the physical and social environment and the utilization of secondary data sources; for example, administrative data and commercial market research data (Bader *et al.*, 2010). The neighborhood food environment was usually measured using proximity to or density of food outlets. In measuring food environments, researchers have typically adopted secondary data from three types of sources: commercial (i.e., InfoUSA, Dun & Bradstreet), government (i.e., agricultural department), and noncommercial (i.e., Yellow Pages). Although using these secondary databases may have time- and labor-saving advantages, it was criticized that there may be problems of data accuracy (Kowaleski-Jones *et al.*, 2009). To improve the accuracy of secondary data sources, a few studies to date have examined the data validity using on-the-ground verification, but the verification results varied (Cummins & Macintyre, 2009; Liese *et al.*, 2010; Bader *et al.*, 2010; Han *et al.*, 2012).

Another concern of using secondary commercial data sources was the significant cost for purchasing the commercial database, although it would save more time and labor in research compared with conducting ground fieldwork to observe neighborhood food environments. An economically preferred alternative data source is the local government database, which lists all food outlets in a defined local area. Recently, a few studies have attempted to explore alternative data sets provided by government sources in local areas of the United States (Wang *et al.*, 2006;

Kowaleski-Jones *et al.*, 2009; Liese *et al.*, 2010). Similar to commercial databases, the government database also has the concern of accuracy and needs to be verified before being commonly used by researchers.

The objectives of this study were: (1) to assess the comparability of two commercial databases, InfoUSA and Dun & Bradstreet, on the measure of food outlets within Los Angeles County in California in 2000; (2) to assess the comparability of databases from government and commercial sources on food outlets within Los Angeles County in 2009; (3) to explore the census tract characteristics among census tracts with low versus high similarity of food store counts obtained from different data sources. The setting of this study was in the Los Angeles County, 2000 and 2009.

The research questions pertinent to our study aims are as follows:

1) Are the food store counts provided by two commercial databases, InfoUSA and Dun & Bradstreet, comparable within Los Angeles County in California in 2000?

2) Are the food store counts provided by government and commercial sources comparable within Los Angeles County in California in 2009?

3) Are the census tract characteristics different between census tracts with low versus high similarity in food store counts obtained from different data sources?

Methods

Study Data and Measures

This study used two databases from commercial sources: InfoUSA and Dun & Bradstreet, and one database from a government source: the Los Angeles County Department of Public Health (LACDPH). First, we compared the grocery store counts in 2000, estimated by InfoUSA and Dun & Bradstreet. Afterward, we compared the counts of a variety of food stores in 2009 obtained from the government database and the Dun & Bradstreet database. Based on the findings of previous comparisons, we further explored the census tract characteristics among census tracts with low versus high similarity of food store counts between different databases. Information on census tract characteristics, including census tract median income and percent of ethnic minority residents, came from the U.S. 2000 Census files.

The InfoUSA database categorized stores using the six-digit InfoUSA-defined Standard Industrial Classification (SIC) codes: the first four digits are standard as defined by the U.S. Department of Labor; the last two digits are InfoUSA-defined subcategories, which provide added resolution to the standard SIC codes. In this set of analysis, we focused on grocery stores (i.e., first four digits of SIC code fall under 5411) in the InfoUSA data. We also obtained grocery store information from the Dun & Bradstreet database, which has standard three-digit and eight-digit SIC information. Since the coding system was not exactly identical in these two databases, we first determined a comparable classification of grocery stores. The detailed classification and corresponding SIC codes were listed in table 1.

The government food store listing data were obtained from the food store records provided by the Los Angeles County Department of Public Health in 2009. Food store records in this database were confirmed by telephone survey; thus, we were able to clean the database and categorize food stores. The food store classification categories used in this study are as follows: chain supermarkets, independent grocery stores, convenience stores, meat and fish markets, sweets, bakeries, fast-food restaurants, pizza restaurants, and liquor stores. To assess the comparability between LACDPH database and Dun & Bradstreet, we recategorized the food store classification used in Dun & Bradstreet database, and the recoded classification corresponded with the classification that we have applied to the LACDPH database. The second set of food store classification and corresponding SIC codes were presented in table 2.

To validate the comparability of different databases, we aggregated the food store counts at the census tract level and conducted comparison analysis based on the unit of census tract. According to the U.S. 2000 Census files, there are 2,054 census tracts in total in Los Angeles County. The primary variable we used is the count of each type of food store per census tract. When comparing store counts in different databases, we defined that the similar store count refers to that store count per census tract were either identical or differed within one store count between two databases. We also computed the percent agreement between databases as to the presence or absence of stores within each category in each census tract. Additionally, we computed store density (i.e., the number of each type of store per square mile in each census tract) and we compared the correlation between store densities estimated by databases.

Statistical Analysis

Data were analyzed using SAS version 9.1.3 (SAS Institute Inc., Cary, NC, USA). Descriptive analysis was applied for estimating the food store counts per census tract. Spearman correlation coefficient was computed to assess the correlation between store densities. In addition, we used two-sample t-tests with unequal variance to compare census tract median income and percent of ethnic minority residents between census tracts with low versus high similarity of store counts. The significant P-value was set at 0.05 or less.

Result

Comparing the Grocery Store Counts per Census Tract in 2000 Estimated by Data from InfoUSA and Dun & Bradstreet

According to our defined grocery store classification, within Los Angeles County in 2000, there were 2,019 supermarkets and grocery stores listed in the InfoUSA data and 1,331 supermarkets and grocery stores listed in the Dun & Bradstreet data. In terms of the total number of convenience stores, the InfoUSA data provided 531, and the Dun & Bradstreet data listed 892.

Comparing the store counts per census tract provided by InfoUSA and Dun & Bradstreet in 2000, we found that 79.2% of census tracts have similar counts of supermarkets and grocery stores; 93.4% of census tracts have similar counts of convenience stores (Table 3). The agreement on presence or absence of stores in the category of supermarkets & grocery category and convenience stores was 63% and 68%, respectively. Overall, the correlation of store densities per census tract between InfoUSA and Dun & Bradstreet data was moderate: 0.27 for supermarkets and grocery stores, and 0.22 for convenience stores. For census tracts with similar counts of supermarkets & grocery stores and convenience stores, the corresponding Spearman's correlation coefficients were 0.34 and 0.29, respectively. For census tracts with dissimilar counts, the Spearman's correlation coefficients were -0.09 and -0.49, respectively.

Census tract median income was higher in census tracts with similar counts of supermarkets & grocery stores and convenience stores. Percent ethnic minority was higher in census tract with dissimilar counts of supermarkets & grocery stores (Table 5).

Comparing Food Store Counts per Census Tract in 2009 Estimated by Data from Los Angeles County Department of Public Health and Dun & Bradstreet

Table 2 showed the description of food stores classification used in comparing LACDPH data and Dun & Bradstreet data in 2009. Convenience stores, fast-food stores, and liquor stores showed considerable discrepancy in the store counts provided by two databases. Table 4 showed that all categories of food stores except fast-food stores (56.67%) and liquor stores (78.75%) showed high percentages (ranged from 88.02% to 99.07%) of similar store counts per census tract between two databases. The percent of census tracts with agreement on presence or absence of stores in a category was highest for bakeries (90%) and chain supermarkets (85%) and lowest for fast-food stores (42%) and liquor stores (44%). However, low level of correlation for store density per census tract between the government data and Dun & Bradstreet data was observed, particularly for chain supermarkets, bakery stores, convenience stores, and liquor stores. For census tracts with similar store counts, Spearman's correlation coefficient ranged from 0.12 (liquor stores) to 0.28 (fast food places); for census tracts with dissimilar store counts, Spearman's correlation coefficients ranged from -0.77 (independent grocery stores) to 0.06 (fast food places).

We subsequently investigated the characteristics of census tracts with low versus high similarity in store counts per census tract between the LACDPH data and Dun & Bradstreet data. Findings indicated that, compared with those census tracts with similar store counts, census tracts with dissimilar counts of independent grocery stores, convenience stores, meat markets, and liquor stores had lower median household income on average. Moreover, census tracts with low similarity in the counts of independent grocery stores and meat markets had a higher percentage of minority residents, while census tracts with low similarity in the counts of sweets stores, fast-food stores, and pizza stores had lower percentage of minority residents (Table 5).

Discussion

Recently the influences of environmental determinants on obesity have been confirmed by empirical evidence. Scholars have proposed the concept and definition of neighborhood food environments, but the lack of valid and reliable measures may affect the interpretations of research findings. This study aimed to assess the comparability of various secondary databases used to measure neighborhood food environments. Overall, our comparisons between two commercial secondary databases and between a commercial and a government database indicated comparable counts of food outlets in most categories examined. The low to moderate correlations in store density were possibly due to the data distribution and the influences of outliers (shown in Table 6 which presented the percent distribution of difference in food establishment count per census tract by category). Meanwhile, we found the considerable discrepancy in the number of store counts listed in LACDPH and Dun & Bradstreet data, which was possibly resulted from different store classification approaches. The classification bias of grocery stores in commercial data sources has been suggested recently (Han *et al.*, 2012), but the classification bias for other food store categories in more diverse data sources also requires inquiries. Additional work is needed to assess whether these dissimilarities in store counts are due to undercounts by the government database, overcounts by the commercial database, or some combination of the two. Researchers should be cautious about the variation of information provided by different databases when using secondary data sources to measure neighborhood food environment.

The comparability of secondary data sources might be challenging in poor neighborhoods. According to our findings, the Los Angeles County census tracts with dissimilar counts of grocery stores, convenience stores, meat markets, and liquor stores were more likely to have lower median household income compared with census tracts with similar store counts. In other words, there was more dissimilarity between databases in census tracts with lower socioeconomic status. This discrepancy was alarming because it might imply that the quality of secondary food environment databases were problematic in neighborhoods where socioeconomically disadvantaged people reside. Previous literature has revealed that the people residing in poor neighborhoods were the risk groups of having poor accessibility to healthy food (Diez-Roux *et al.*, 1999; Morland, Wing, & Diez-Roux, 2002; Powell *et al.*, 2007), and they were the vulnerable population that researchers and public health policymakers are primarily concerned about. The accurate estimation of food environment information in certain neighborhoods was particularly important in future public health research. In addition, it was interesting that we found different patterns regarding racial/ethnic composition among census tracts with low similarity in counts of different store categories. According to our results, the LACDPH and commercial databases were less comparable in measuring counts of grocery stores and meat markets in census tracts with more minority residents. Furthermore, in census tracts with fewer minority residents, the estimated counts of sweets stores, fast-food stores, and pizza stores were less equivalent between government and commercial databases. To our knowledge, this is the first study to date comparing census tract characteristics based on the agreement level of secondary data sources. Once we identified that existing secondary databases were less comparable in certain census tracts, future research should recognize the discrepancy and continue to pursue methodology improvement.

Limitations of this study should be considered. First, this study was not designed to verify the true number of food outlets in a defined neighborhood, and we couldn't make inferences or conclusions with regard to the accuracy of the three study databases. Store names and addresses in Dun & Bradstreet data were unavailable for our analysis; therefore, we couldn't verify matched store records by comparing the store name and location in different databases.

Second, each commercial database company had a distinct strategy for data collection and management, and it could influence the comparability among databases, despite the fact that we had already recategorized the food store classification before conducting analyses. Commercial databases serve for commercial purpose and provide business related information, which was not necessary appropriate for the use in health related research. Wang *et al.* (2006) indicated that the store listings provided by Yellow Pages could be problematic for measuring food environment because the store addresses sometimes didn't reflect the physical location of the store. Moreover, each data source may update information with different frequency. For instance, Dun & Bradstreet and InfoUSA updated store-listing information at least annually, while LACDPH data were updated when store licenses were renewed.

Third, the data provided by the Los Angeles County Department of Public Health may include only food outlets that followed the government regulations, while the commercial databases collected more extensive information from diverse sources as they collect information for business purposes. We encourage future development and application of additional alternative secondary data sources, which provide reliable information on the measure of neighborhood food environments. Meanwhile, future studies conducting on-the-ground verification for secondary databases in order to improve current methodology gap regarding the measure of neighborhood food environment and the accuracy of store classification in various databases are recommended.

Table 1. Operational definition of grocery stores classification used in comparing InfoUSA and Dun & Bradstreet data

Data	Food Store Definition and corresponding SIC codes [a]		No. of Stores Listed
InfoUSA	**Supermarkets and grocery stores** [b]		2,019
	SIC 541101	Food markets	
	SIC 541105	Grocers retail	
	Convenience stores		531
	SIC 541103	Convenience stores	
Dun & Bradstreet	**Supermarkets and grocery stores**		1,331
	SIC 54110100	Supermarkets (uncategorized)	
	SIC 54110101	Supermarkets, chain	
	SIC 54110103	Supermarkets, independent	
	SIC 54119904	Grocery stores, chain	
	SIC 54119905	Grocery stores, independent	
	Convenience stores		892
	SIC 54110200	Convenience stores (uncategorized)	
	SIC 54110201	Convenience stores, chain	
	SIC 54110202	Convenience stores, independent	

[a] The InfoUSA data used specific six-digit SIC codes and Dun & Bradstreet data used standard eight-digit SIC codes to classify stores.

[b] The supermarkets and grocery stores can not be classified separately in the InfoUSA data.

Table 2. Operational definition of food stores classification used in comparing government data and Dun & Bradstreet data

Food Stores Classification	SIC code	Food Store Definition	No. of Stores Listed	
			Government Data	Dun & Bradstreet
Chain supermarkets	54110101	Supermarkets, chain	168	309
Convenience stores	54110200	Convenience stores (uncategorized)	370	1,248
	54110201	Convenience stores, chain		
	54110202	Convenience stores, independent		
Independent grocery stores	54119905	Grocery stores, independent	359	645
Meat and fish markets	542	Meat and fish markets	98	828
Sweets stores	544	Candy, nut, and confectionery stores	551	1,181
	54619903	Cakes		
	54619904	Cookies		
	54619905	Doughnuts		
	54619906	Pastries		
	54619907	Pies		
	54619908	Pretzels		
Bakery stores	54619901	Bagels	220	133
	54619902	Bread		
Fast food stores	58120300	Fast food restaurants and stands	746	4,086
	58120301	Box lunch stand		
	58120302	Carry-out only (except pizza) restaurant		
	58120303	Chili stand		
	58120304	Coffee shop		
	58120305	Delicatessen (eating places)		
	58120306	Drive-in restaurant		
	58120307	Fast-food restaurant, chain		
	58120308	Fast-food restaurant, independent		
	58120309	Food bars		

Table 2 (continued)

Food Stores Classification	SIC code	Food Store Definition	No. of Stores Listed	
			Government Data	Dun & Bradstreet
	58120310	Grills (eating places)		
	58120311	Hamburger stand		
	58120312	Hot dog stand		
	58120313	Sandwiches and submarines shop		
	58120314	Snack bar		
	58120315	Snack shop		
Pizza Stores	58120600	Pizza restaurants (uncategorized)	246	1151
	58120601	Pizzeria, chain		
	58120602	Pizzeria, independent		
Liquor stores	592	Liquor stores	180	1,901

Table 3. Comparison of store counts per census tract from InfoUSA and Dun & Bradstreet, Los Angeles County, 2000

Food establishment category	Percent of census tracts with similar counts in both databases [a]	Percent of census tracts in which databases agreed on presence/absence of stores in category	Spearman's correlation coefficient for store density [b]
Supermarkets and grocery stores	79	63	0.27 ***
Convenience stores	93	68	0.22 ***

* $p<.05$; ** $p<.01$; *** $p<.001$

[a] Store counts per census tract differed by no more than one store.

[b] Store density is the number of each type of store per square mile in the census tract.

Table 4. Comparison of store counts per census tract from LACDPH and Dun & Bradstreet, Los Angeles County, 2009

Food establishment category	Percent of census tracts with similar counts in both databases [a]	Percent of census tracts in which databases agreed on presence/absence of stores in category	Spearman's correlation coefficient for store density [b]
Grocery stores			
Chain supermarkets	99	85	0.07 ***
Independent grocery stores	97	70	0.14 ***
Convenience stores	88	57	0.09 **
Meat and fish markets	93	71	0.15 ***
Sweets	90	64	0.18 ***
Bakery	99	90	0.09 **
Eating places			
Fast food restaurants	57	42	0.32 ***
Pizza restaurants	89	63	0.20 ***
Liquor stores	79	44	0.07 **

* $p<.05$; ** $p<.01$; *** $p<.001$

[a] Store counts per census tract differed by no more than one store.

[b] Store density is the number of each type of store per square mile in the census tract.

Table 5. Comparison of sociodemographic characteristics of census tracts with similar vs. dissimilar store counts as estimated by different databases, by establishment category

Food establishment category	Median household income ($1000): mean (SD)			Percent minority: mean (SD)		
	Similar store counts [a]	Dissimilar store counts	P-value	Similar store counts [a]	Dissimilar store counts	P-value
Comparison between InfoUSA and Dun & Bradstreet, 2000						
Supermarkets and grocery stores	48.9 (26.3)	37.4 (16.0)	***	65.5 (28.8)	76.7 (25.3)	***
Convenience stores	46.9 (25.4)	40.2 (16.3)	***	67.7 (28.6)	70.6 (26.4)	
Comparison between LACDPH and Dun & Bradstreet, 2009						
Chain supermarkets	46.5 (25.0)	44.2 (19.2)		67.9 (28.4)	61.7 (31.1)	
Independent grocery stores	46.8 (25.0)	34.6 (17.5)	***	67.5 (28.7)	82.1 (27.0)	***
Convenience stores	47.2 (25.8)	41.6 (17.4)	***	67.6 (28.6)	69.9 (20.6)	
Meat and fish markets	47.4 (25.4)	35.7 (15.5)	***	66.8 (28.5)	81.4 (23.8)	***
Sweets	46.5 (25.4)	46.1 (20.9)		68.5 (28.6)	61.8 (26.7)	**
Bakeries	46.5 (25.0)	46.3 (22.2)		68.0 (28.4)	58.8 (31.2)	
Fast food restaurants	47.2 (27.2)	45.6 (21.6)		70.5 (28.7)	64.4 (27.8)	***
Pizza restaurants	46.2 (25.5)	48.4 (20.5)		69.2 (28.5)	57.6 (26.1)	***
Liquor stores	47.3 (25.9)	43.6 (20.7)	**	67.9 (28.5)	67.9 (28.3)	

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

[a] Similar store counts per census tract differed by no more than one store.

Table 6. Percent distribution of difference in food establishment count per census tract [a] by category (LACDPH vs Dun & Bradstreet)

Food establishment category	Number of census tracts	-3+	-2	-1	0	1	2	3+
Grocery stores								
Chain supermarkets	2054	0	0.7	11.7	84.4	3.0	0.2	0.1
Independent grocery stores	2054	0.1	1.7	23.7	68.6	5.1	0.8	0.1
Convenience stores	2054	2.9	8.4	28.4	55.0	4.6	0.6	0.1
Meat and fish markets	2054	1.9	5.4	21.5	70.2	1.0	0.1	0.1
Sweets	2054	2.6	6.2	24.8	60.4	4.8	0.9	0.3
Bakery	2054	0.5	4.8	89.4	4.8	0.4	0.1	0.5
Eating places								
Fast food restaurants	2054	25.7	17.0	22.9	31.7	2.0	0.4	0.3
Pizza restaurants	2054	3.5	7.7	24.5	61.3	2.7	0.2	0.1
Liquor stores	2054	7.1	13.8	36.2	41.5	0.9	0.3	0.1

[a] Calculated as LACDPH count – Dun & Bradstreet count

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Chapter 5. Summary and Conclusions

Summary of Findings

The overall purpose of this dissertation was to examine multilevel determinants of childhood obesity, including maternal employment, individual- and neighborhood-level SES, neighborhood food environment, and household grocery shopping distance. Specifically, the first objective was to investigate the associations between children's BMI and maternal employment, individual-level SES, and neighborhood-level SES. The second objective was to investigate the associations between children's BMI, neighborhood food environment, and household grocery shopping distance. Our third objective was to assess the comparability of neighborhood food environment databases obtained from governmental and commercial sources.

In our first study, we found significant effect of maternal part-time employment on increased child's BMI when we fitted the regression model controlling for individual SES; but this effect disappeared after we adjusted for both individual and neighborhood SES. We also found that both individual- and neighborhood-level SES measures were inversely related to childhood obesity, and the neighborhood-level SES was a stronger predictor of childhood obesity compared to the individual-level SES, which was inconsistent with the results concluded by a previous review study (Janssen *et al.*, 2006). Additionally, we found that children's TV-watching time mediated the association between maternal part-time employment and children's BMI increase, which in part confirmed the supervision hypothesis provided by previous literature (Fertig, Glomm, & Tchernis, 2009).

Results of the second study indicated that children living in neighborhoods with lower density of supermarkets and grocery stores or living in neighborhoods with higher density of convenience stores were more likely to have higher BMI, after we accounted for multilevel covariates including sociodemographics, household grocery shopping distance, car ownership, and neighborhood SES. Our findings also showed that household grocery shopping distance was neither a mediator nor a moderator of the relationship between neighborhood food environment and childhood obesity.

The third study tested the agreement of neighborhood food environment data obtained from different sources. For the InfoUSA vs. Dun & Bradstreet comparison, similarity of counts was high for supermarkets & grocery stores and convenience stores. In terms of the comparison between Los Angeles County Department of Public Health and Dun & Bradstreet databases, similarity of counts was high for chain supermarkets, independent grocery stores, meat and fish markets, sweets stores, and bakeries; similarity of counts was low for fast-food stores and liquor stores. Furthermore, we identified that census tract characteristics (i.e., median income, percent minority) were associated with levels of similarity across databases. On average, census tracts with dissimilar counts of grocery stores, convenience stores, meat markets, and liquor stores had lower median household income, compared to census tracts with similar store counts. Moreover, census tracts with dissimilar counts of grocery stores and meat markets had higher percentage of minority residents, while census tracts with dissimilar counts of sweets stores, fast food stores, and pizza stores had lower percentage of minority residents.

Future Research Directions

This dissertation examined multilevel determinants of childhood obesity and our findings suggested that neighborhood-level factors significantly contributed to the risk of childhood obesity. Similar to the findings documented in previous studies (Diez-Roux *et al.*, 1999;

Morland, Wing, & Diez-Roux, 2002; Powell *et al.*, 2007), both neighborhood SES and neighborhood food environment were identified as important predictors of increased child's BMI in this dissertation. Our findings are likely to support policies addressing the changes in obesogenic environments, such as improving the accessibility to food stores that provide healthy foods rather than energy-dense foods. Moreover, the disparities in the risk of childhood obesity among the economically disadvantaged communities will also be important concern for future health intervention and policy. Although the broad association between environmental factors and obesity was proposed, we should not ignore that the environmental effects can be moderated or mediated by a number of individual and social factors. Moreover, the neighborhood selection bias should be considered when researchers conduct multilevel studies and interpret study findings.

Previous literature has documented the positive relationship between maternal employment and childhood obesity (Anderson, Butcher, & Levine, 2003; Cawley & Liu, 2007; Fertig, Glomm, & Tchernis, 2009; Brown *et al.*, 2010), our study further revealed the influence of part-time employment. The association between maternal nonstandard work schedules and childhood obesity has been rarely investigated and we suggest future study should continue inspecting various types of nonstandard work schedules and accumulate more extensive evidence. Additionally, future study should continue clarifying existing controversies regarding the modifying effects of individual level SES on the association between maternal employment and childhood obesity, although the modifying effect was not observed in our study.

The measures of individual- and neighborhood- level SES are issues to be discussed. One of the strengths of our studies was to adopt composite measures of individual- and neighborhood-level SES, but more comprehensive measures of SES, particularly at neighborhood level such as safety, green space, and social capital, are recommended for future research. The potential pathways of how both individual SES and neighborhood SES influence obesity and other health outcomes are important topics to examine.

For the measure of neighborhood food environment, the accuracy of secondary data sources remains a considerable issue and it needs to be explored and solved by more validation studies. There are a variety of approaches to improve the measure of neighborhood food environment: conducting on-the-ground validation, validating existing secondary data sources, and seeking alternative data sources. We encourage continuing exploration of government administrative data, and suggested subsequent studies to link reliable measure of neighborhood food environment with obesity-related health outcomes. Furthermore, the development of more alternative proxy measures of food environment is recommended. For example, a recent study has reported that self-reported measures of food availability can also be feasible proxy measures of directly assessed food availability (Moore, Diez Roux, & Franco, 2012). Finally, in addition to the physical food environment addressed in this dissertation, the concept and measure of food environment involved consumer perceptions of food environment, which reflects what consumers encounter within and around food outlets, including price, placement, available choices, food quality, and nutrition information (Glanz *et al.*, 2005). This domain also requires assessments and it may be linked with multilevel determinants of obesity in future studies.

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