NEURAL TUBE DEFECT, HEART DEFECT, ORAL CLEFT AND THEIR GEOSPATIAL ASSOCIATIONS WITH SUPERMARKET AND CONVENIENCE STORES IN THE CITY OF DALLAS, TEXAS

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Birth defects are the leading cause of infant death in the United States. Research has linked poor maternal micronutrient intake to birth defects including neural tube defects, heart defects, and oral clefts. After investigating spatial patterns of these birth defects in the City of Dallas and the neighborhood characteristics within clusters, geospatial access to supermarkets and convenience stores measured by proximity and concentrations are examined as environmental risk factors for nutrition-related birth defects.

Spatial clusters of all three nutrition-related birth defects exist in the City of Dallas. Cluster for NTD occurs in vulnerable places with lower income and high minority population specifically Hispanics with no supermarkets. Cluster for heart defects mostly occurs in high income and predominantly white neighborhoods with many supermarkets. Clusters of oral clefts mostly occurs in middle-class income with relatively high minority populations with many convenience stores.

For the entire study area, geographical access to supermarkets that include healthy foods are shown to be spatially reachable from most of mothers of infants with nutrition-related birth defects as well as convenience stores that typically include the majority of unhealthy processed foods with very few nutrients. Thus, not only easy geographical access to healthy food vendors but to convenience stores with low quality produces is observed at the same time.

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TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Birth Defects

Major birth defects are conditions that are exhibited at birth that cause structural uniqueness in more than one part of the body. Birth defects that occur while the fetus is developing in the mother's body can include defects of various body parts including limbs, mouth, the spinal cord, reproductive organs, and internal organs. They can cause a serious adverse effect on anatomy and further, development. Some birth defects can be detected before birth, others can be detected when the baby is born, and some may not be detected until sometime later after birth.

Birth defects are the leading cause of infant mortality in the United States, accounting for 21% of all infant deaths in 2006 (Heron et al., 2009) (CDC, 2011). According to Texas Department of State Health Services (2008), in Texas, more than 17,000 babies are born each year with one or more birth defects, and nearly two-thirds of birth defects are caused by unknown factors, thus requiring concerted efforts towards better understanding of contributing factors as well as public health interventions. This thesis seeks to examine the geography of birth defects in the City of Dallas and the explanatory factors.

Nutrition-Related Birth Defects

Birth defects can affect almost any part of the body, varying from mild to severe conditions. For the purpose of this study, birth defects of interest are classified into three major groups – neural tube defects, heart defects and oral clefts. Birth defects among most infants occur as the result of a combination of genetics and other risk factors, such as environmental exposures, maternal diet, or maternal medication use.

Neural Tube Defects (NTD)

As a part of neural tube defects (NTD), anencephaly and spina bifida are included in the study. Anencephaly is a serious birth defect in which a baby is born without parts of the brain and skull, and it happens if the upper part of the neural tube does not close all the way. Almost all babies born with anencephaly die shortly after birth. According to CDC (2011), about 1 in every 4,859 babies in the United States is born with anencephaly each year. Spina bifida is a condition with the spine, and it happens anywhere along the spine if the neural tube does not close all the way, often resulting in damage to the spinal cord and nerves, which can lead to both physical and intellectual disabilities.

Low intake of folic acid before getting pregnant and in early pregnancy increases the risk of having a pregnancy affected by NTD. Babies born to Hispanic mothers are at an increased risk for NTD, but reasons for the increased risk among Hispanic mothers are not well understood (Canfield, Annegers, Brender, Cooper, & Greenberg, 1996).

Cigarette smoking including secondhand exposure (Suarez, Felkner, Brender, Canfield, & Hendicks, 2008) and diabetes and obesity are known as risk factors (Anderson et al., 2005) along with lack of nutritious food intake. Maternal hyperthermia from maternal fever or exposures to heat devices such as hot tubs, saunas, or electric blankets has been added as a relatively new finding that is associated with NTD risk (Suarez, Felkner, & Hendicks, 2004).

Heart Defects

Heart defects are conditions that are present at birth and can affect the structure of a baby’s heart and the way it works, including how blood flows through the heart and out to the rest of the body. Heart defects are the most common type of birth defect, and a leading cause of infant death. According to CDC (2011), nearly 40,000 births in the United States are born with heat defects each year. However, this prevalence might be underestimated because some heart defects are not detected until later in life, during childhood or adulthood. Some babies have heart defects because of changes in their genes or chromosomes. Obesity, diabetes, and smoking in pregnant mothers are known risk factors for heart defects (Watkins, Rasmussen, Honein, Botto, & Moore, 2003).

Oral Clefts

Oral clefts are birth defects that occur when a baby’s lip or mouth do not form properly. Oral clefts consist of two conditions, a cleft lip and cleft palate. A baby can have a cleft lip, a cleft palate, or both at the same time. Children with a cleft lip with or without a cleft palate or a cleft palate alone often have problems with feeding and talking. They also might have ear infections, hearing loss, and problems with their teeth. According to CDC (2011), 651 babies in the United States are born with a cleft palate and 4,437 babies are born with a cleft lip with or without a cleft palate.

A cleft lip happens when the tissue that makes up the lip does not join completely before birth, resulting in an opening in the upper lip. The opening in the lip can be a small slit or it can be a large opening that goes through the lip into the nose. A cleft lip can be on one or both sides of the lip or in the middle of the lip, which occurs very rarely.

A cleft palate happens when the tissue that makes up the roof of the mouth does not join correctly. Both the front and back parts of the palate are open for some babies, and only part of the palate is open for others.

Some children have a cleft lip or cleft palate because of changes in their genes. Besides genes and poor maternal diets, other possible risk factors for oral clefts include alcohol use (Munger et al., 1996). In spite of the folic acid effectiveness on other conditions, folic acid fortification has had very little or no effect on the prevalence of oral clefts in infants born in Texas (Hashmi, Waller, Langlois, Canfield, & Hecht, 2005).

CHAPTER 2

LITERATURE REVIEW

Nutrition and NTD, Heart Defects, and Oral Clefts

Folic Acid and NTD

Randomized control trials confirm the effectiveness of folic acid supplementation in preventing NTDs (MRC Vitamin Study Research Group, 1991; Czeizel & Dudas, 1992). Folic acid/folate, a B-vitamin (B-9) that is needed to make healthy new cells, and protein synthesis, also stimulates antioxidant activity. It is found in peas, beans, citrus fruits, and leafy green vegetables (Mitchell et al., 2004).

Due to this compelling evidence, mandatory fortification of enriched cereal grain products with folic acid was authorized in the United States in 1996 and was fully implemented in 1998 by the Food and Drug Administration. The U.S. program adds 140 µg of folic acid per 100 g of enriched cereal grain product and has been estimated to provide 100–200 µg of folic acid per day to women of childbearing age (Quinlivan & Gregory, 2007; Yang et al., 2007; Rader, Weaver & Angyal, 2000). Since the implementation of folic acid fortification in 1998 in the United States, NTD prevalence has decreased between 19%–32%(Williams et al., 2002; Honein, Paulozzi, Mathews, Erickson, & Wong, 2001; Mathews, 2008; Boulet et al., 2008).

Micronutrients and NTD, Oral Clefts, and Heart Defects

In addition to folic acid/folate, previous research has linked poor maternal micronutrient intake. These micronutrients include vitamins, zinc, and copper to birth defects including neural tube defects (NTD), heart defects, cleft lip and palate (Lu & Lu, 2007). Both zinc and copper are found in oysters, livers, low fat meats, and sesame seeds and toasted wheat germ (Keen et al., 2003).

Comprehensive Nutrition and NTD, Oral Clefts, and Heart Defects

Furthermore, combined effects of multiple nutrients and food constituents are suggested to be larger than single nutrient. As a part of more holistic approaches to examine nutritional factors, Bodnar and SiegaRiz (2002) measured diet quality of women by developing “A Diet Quality Index for Pregnancy (DQI-P)” to reflect current nutritional recommendations for pregnancy and national dietary guidelines. The DQI-P includes eight components: % recommended servings of grains, vegetables and fruits, % recommendations for folate, iron and calcium, % energy from fat, and meal/snack patterning score. Proximity of supermarkets, as an indicator of access to comprehensive nutrition has been suggested to increase diet quality of women measured by DQI-P (Laraia, Siega-Ritz, Kaufman, & Jones, 2004). Carmichael et al. (2012) incorporated this DQI-P into birth defects research and found healthier DQI-P to decrease risks of NTDs and clefts, meaning that increased diet quality decreased NTD and cleft rates.

Built Environment on Nutrition

Besides, genetics and behavioral factors, the human ecology model emphasizes the importance of environment by suggesting that disease, specifically nutrition-related birth defects, result from the interaction of three major variables – population (human physiology, gender, age), behavior (socio-cultural practices, political and economic forces), and habitat (natural and built physical and social environments) (Meade & Emch, 2010). Therefore, in considering nutrition associations with birth defects, habitat cannot be ignored. The built environment, particularly the local food environment, is the primary focus of this research, with secondary emphasis on neighborhood characteristics, particularly disadvantaged socioeconomic neighborhood factors as predictors of nutrition-related birth defects.

Food Deserts

Although proximity of supermarkets, as an indicator of access to comprehensive nutrition, has been suggested to increase diet quality of women (Laraia, Siega-Ritz, Kaufman, & Jones, 2004), the issue of lack of access to reasonably priced and nutritious food in low-income neighborhoods is quite widespread in American cities (Morland et al, 2002; Morland & Kimberly, 2002;Moore & Diez Roux, 2006;Sharkey, Horel, Han & Huber, 2009). Built environment where residents are less likely to have access to supermarkets or grocery stores that provide healthy food choices are called “food deserts” (Whitacre, Tsai, & Mulligan, 2009).

In the United States, food deserts tend to be located in urban and rural low-income neighborhoods. Those low-income residents who cannot afford to own cars are unable to reach distant supermarkets and depend on local neighborhood stores (Macintyre, 2007). Eating healthy is difficult when no healthy food but only unhealthy food alternatives are accessible. Convenience stores that tend to have higher prices and lower quality produce that are mass produced and heavily processed with high concentrations of unhealthy fats, carbohydrates, and additives are more common in low-income areas. Whereas, supermarkets that offer healthy foods are rare in such low-income areas (Apparicio, Cloutier, & Shearmur, 2007).

CHAPTER 3

IMPLICATION OF RESEARCH

Study Area

Dallas, Texas, is known to be the home of the largest collections of areas with lack of access to supermarkets in the US (USDA, 2009) and defined by the 2008 Farm Bill as "an area in the United States with limited access to affordable and nutritious food, particularly such an area composed of predominantly lower-income neighborhoods and communities" (USDA, 2009). All population groups are not equally exposed to a lack of healthy foods in Dallas. Berg and Murdoch (2008) found that food deserts areas have an average percentage White that is roughly half that of neighborhoods with an abundance of stores. Food deserts have on average twice the percentage African American that tends to be lower income as neighborhoods with three or more stores.

Interestingly, these two types of neighborhoods differ hardly at all in terms of percentage Hispanic in Dallas. Hence the reason, the City of Dallas within Dallas County is the study area of the study.

Theoretical Framework

Due to its combination with lack of access to nutrition and lack of resources such as money and vehicles, the food deserts in Dallas can be explored through the place vulnerability theory. The theory argues that adverse life circumstances, such as disease (nutrition-related birth defects in the study), do not affect all places uniformly, and that vulnerability to disease is inevitably tied to specific places (food deserts in the study).

The environment, and the place characteristics that comprise it, can shape the spatial patterns of disease, and influence a person's vulnerability to disease (Oppong and Harold, 2009). The study seeks to explore the place vulnerability for nutrition-related birth defects in Dallas, TX.

Study Objectives

First, spatial patterns of birth defects need to be examined, assuming that clusters exist because birth defects can be influenced by a number of factors, such as environmental factors or variations in genetic susceptibility, all of which may vary spatially. Second, based on the place vulnerability theory, areas with high rates of birth defects should be closely examined. Our expectation is that they will occur more in vulnerable places – areas with lower geographical access to healthy foods, lower income, and high minority population. Consequently, we define geographical concentration of supermarkets and convenience stores around nutrition-related birth defects to measure geographical options to obtain healthy food. Based on these study objectives, research questions are defined below:

1. What is the spatial pattern of birth defects in Dallas? Is there evidence of clustering of birth defects (NTD, Heart Defects, and Oral Clefts) in Dallas?
2. What are the place characteristics of the neighborhoods within high birth defect clusters in Dallas?
3. Is geospatial access to supermarkets and convenience stores related to birth defects?
    a) What is the median proximity to supermarkets and convenience stores from mothers' residence of infants with nutrition-related birth defects?
    b) How does the concentration of supermarkets and convenience stores differ, depending on the distances to each birth defect?

The purpose of this study is to help public health decision makers identify areas that should be targeted for increased nutrition- related birth defects surveillance, intervention and treatment. In addition, for maximum prevention of the suggested nutrition-related birth defects, we examine whether nutrients-fortified food products and diets that include recommended multiple nutrients are spatially reached to all women of reproductive ages and pregnancy effectively.

CHAPTER 4

DATA

Birth Defects (NTDs. Heart Defects, and Oral Clefts)

The data for NTD, heart defects, and oral clefts come from the Texas Birth Defects Epidemiology and Surveillance Branch. Cases are not individual children rather conditions because a child may have multiple birth defects. All birth defects data on live-born or dead, aborted fetuses are included because excluding dead or aborted defects result in counts and rates that are somewhat incomplete . Especially for the conditions that only contain very small case numbers such as NTDs, additional geospatial information that can be gained by adding dead and aborted cases are valuable. All records in the above datasets are for children who meet the following criteria: born in 1999 through 2009, born to mothers who resident in the City of Dallas, they need to have a geocoded maternal address at delivery, the mother cannot have diabetes, and cases must be a completed case in the Texas Birth Defects Registry. Although this is individual point data which is the smallest geographical scale possible, the data is utilized within both individual and aggregated zip-code level in this study.

Live Births

Apart from meeting the inclusion criteria, all controls are live births without any birth defect condition. For cluster analysis to identify high risk areas of each birth defect, all the live births born between 1999 to 2009 are obtained from vital statistics within Texas Department of State Health Services. Since sampling controls randomly in terms of geography is still a new challenge, whole live births data during the timeline is employed, rather than sampling controls. However, in order to get valid inference with the analysis with Satscan software, the geographical units must be the same for the cases and controls, live births. Since live births data are only available within zip-code level, individual-level point case data including all NTDs, heart defects, and oral clefts are aggregated into zip-code level as well.

Food Stores

Data regarding food establishments are obtained from the department of food inspection of the City of Dallas to be geocoded to the street-address level so that it is successfully jointed to the birth defects data that are street-address level. Using the North America Industry Classification System (NA-ICS) codes and definitions, overall categories of food stores are identified as supermarkets and convenience stores.

Supermarkets are defined as large national chain stores, and convenience stores are defined as smaller grocery retailers and convenience stores that do not have gas pumps such as local mom and pop grocery stores. These two stores are selected based on two factors: 1) To be defined as the availability of food stores to carry out to home. 2) To distinguish and contrast supermarkets widely known as healthy food vendors and convenience stores known as its low quality produces.

Census

Using the 2000 SF-3 in the U.S. Bureau of the Census, percent(%) race/ethnicity (the number of certain race/ethnicity divided by total population) and income variables are employed within the zip-code level as a demographic marker, more specifically, to quantify vulnerable places with lower income and high minority population. Income status contains three categories (extremely poor, household income, and high income). However, in this study, they are also converted into numerical (1 for extremely poor, 2 for household income, and 3 for high income) to get the means of multiple zip-codes. For race/ethnicity, only white, black, and Hispanics are extracted to be consistent with previous research by Berg and Murdoch (2008), and two largest minority groups in Dallas that are simultaneously identified as high birth defect risk groups are Hispanics and blacks. This census data are extracted within zip-code level to be linked with zip-code level clusters. By linking this location-based socioeconomic data to areas with high birth defect clusters, income status and minority percentages are examined as an indicator of place vulnerability, based on place vulnerability theory. In addition to these socioeconomic data, centroids for each zip-code within the study area are obtained from the Census 2000 for the use of coordinate files to run through Satscan software for cluster detection. Thus, all of these census data are extracted to be jointed and related to spatial cluster analysis.

CHAPTER 5

METHODS

Bernoulli Cluster Analysis

To address Research Question 1(What is the spatial pattern of birth defects in Dallas? Is there evidence of clustering of NTDs, heart defects, and oral clefts in Dallas?), Bernoulli cluster analysis is conducted with SaTScan software to investigate clusters of each birth defect. For each window location and size, the number of observed and expected observations are calculated inside the window and, in turn, calculates the likelihood function for each window, the form of which differs depending on the assumed distribution of events. For the Bernoulli model, the zip-code level cases and controls are split into separate point shapefiles for comparison and got imported into SaTScan and analyzed using the Bernoulli method to determine if there is significant clustering of the case location distribution as compared to the controls location distribution. The advantage of this method is that it is independent of the underlying population distribution (Kulldorff, 1997).

The SaTScan Bernoulli model uses a likelihood ratio test of the probability of a group of patients within a potential cluster defined by a circle being a case versus a control. The likelihood function for the Bernoulli model is:

$$\left(\frac{c}{n}\right)^{c}\left(\frac{n-c}{n}\right)^{n-c}\left(\frac{C-c}{N-n}\right)^{C-c}\left(\frac{(N-n)-(C-c)}{N-n}\right)^{(N-n)-(C-c)}$$

where C is the total number of cases, c is the observed number of cases within the window, n is the total number of cases and controls within the window, N is the combined total of cases and controls within the data set.The likelihood ratio is tested for significance using the Monte Carlo method. A circular window is centered on zip-code centroid, and the diameter is varied from zero to one that includes a certain maximum proportion of the total number of case events.

For the purposes of this analysis, 999 Monte Carlo replications are used, the maximum circle size included up to 10% of the total cases being analyzed, and a significant p-value was less than 0.05. The likelihood function is maximized over all window locations and sizes and the one with the maximum likelihood constitutes the most likely cluster. Clusters of each birth defect are mapped for visualization with ArcGIS 10.1. To address Research Question 2 (What are the neighborhood characteristics of high birth defect cluster areas in Dallas?), census-based race/ethnicity and income data for all the zip-codes within detected high clusters are incorporated into zip-code based clusters of birth defects.

Proximity Network Detection

To address Research Question 3 a (what is the median proximity to supermarkets and convenience stores from mothers' residence of infants with nutrition-related birth defects?), after geocoded to the street-address level, street addresses of mother's residency at birth and street addresses of supermarkets and convenience stores are linked by network analyst extension in Arc GIS 10.1 to measure proximity of stores (distance between residence and food stores) in the City of Dallas. The shortest network distances between the paired points, the mother's residency of infants with nutrition-related birth defects and each of the nearest stores are calculated along the road network.

Bivariate K Function

To address Research Question 3 b(How does the concentration of supermarkets and convenience stores differ, depending on the distances to each birth defect?), a multi-distance cluster analysis method, bivariate K function, is employed as the suitable technique for the following reasons. It assesses the relationship between two point patterns: (a) the spatial distribution of supermarkets and convenience stores, and (b) the spatial patterns of nutrition-related birth defects. A benefit of the K function method is that it provides a statistical basis for evaluating evidence of spatial dependence (i.e. clustering or dispersion) over a range of distance thresholds. The bivariate K function method estimates the spatial dependence between two different types of point patterns that are bounded by a predefined geographic region. This is done by identifying distances within which spatial dependence is evident and testing the statistical significance of the observed clustering relative to an expected distribution of points if there is no spatial dependence.

The R software is used for this analysis. The Splancs package provides the bivariate K function and the PBSMapping package provides GIS capabilities. This method has been used previously to evaluate the relationship between the point location of fast-food restaurants and schools in Chicago (Austin, Melly, Sanchez, Patel, Buka, & Gortmaker, 2005). The K function is formally defined by Gatrell,el al. (1996) as:

$$\lambda K(d)=E$$

where E represents # events within distance d of an arbitrary event and K(d) defines the spatial dependence between two events within distance thresholds as defined by d.

In this study, E provides the expectation of the number of nutrition-related birth defects that are within d (where d=0 to 10000 meters) of supermarkets and convenience stores. An L transformation was applied to standardize the K function. The L transformation is commonly applied to problems of this nature in order to standardize the K value and is defined as L function(k,s) = sqrt(k/pi)-dist.s .

The spatial dependence between two point patterns are classified as “clustered” if they lie above the theoretical bounds that are determined using Monte Carlo simulations. Conversely, the spatial dependence between two point patterns is classified as “dispersed” if they lie below the theoretical bounds.

CHAPTER 6

RESULTS

Bernoulli Cluster Analysis

First of all, 113 NTDs, 2379 heart defects, and 349 oral clefts are geographically-referenced in the City of Dallas. With SatScan cluster analysis, clusters of all NTDs, heart defects, and oral clefts are confirmed to exist after proving the statistical significance. 1 zip-code, 4 zip-codes, and 10 zip-codes are detected within a cluster of NTDs, heart defects, and oral clefts, respectively. Oral clefts have got the largest cluster, and NTD has got the smallest cluster. Interestingly, the pattern of each cluster differs from among all of the three defects except one zip-code that overlaps within both NTD and clefts. No supermarkets and 2 convenience stores are observed in NTD cluster. 4 supermarkets and 20 convenience stores are observed in heart defect cluster. 9 supermarkets and 40 convenience stores are observed in oral cleft cluster. Therefore, cluster for NTD contains no supermarkets; cluster for heart defects contains many supermarkets; cluster of oral clefts mostly contains many convenience stores.

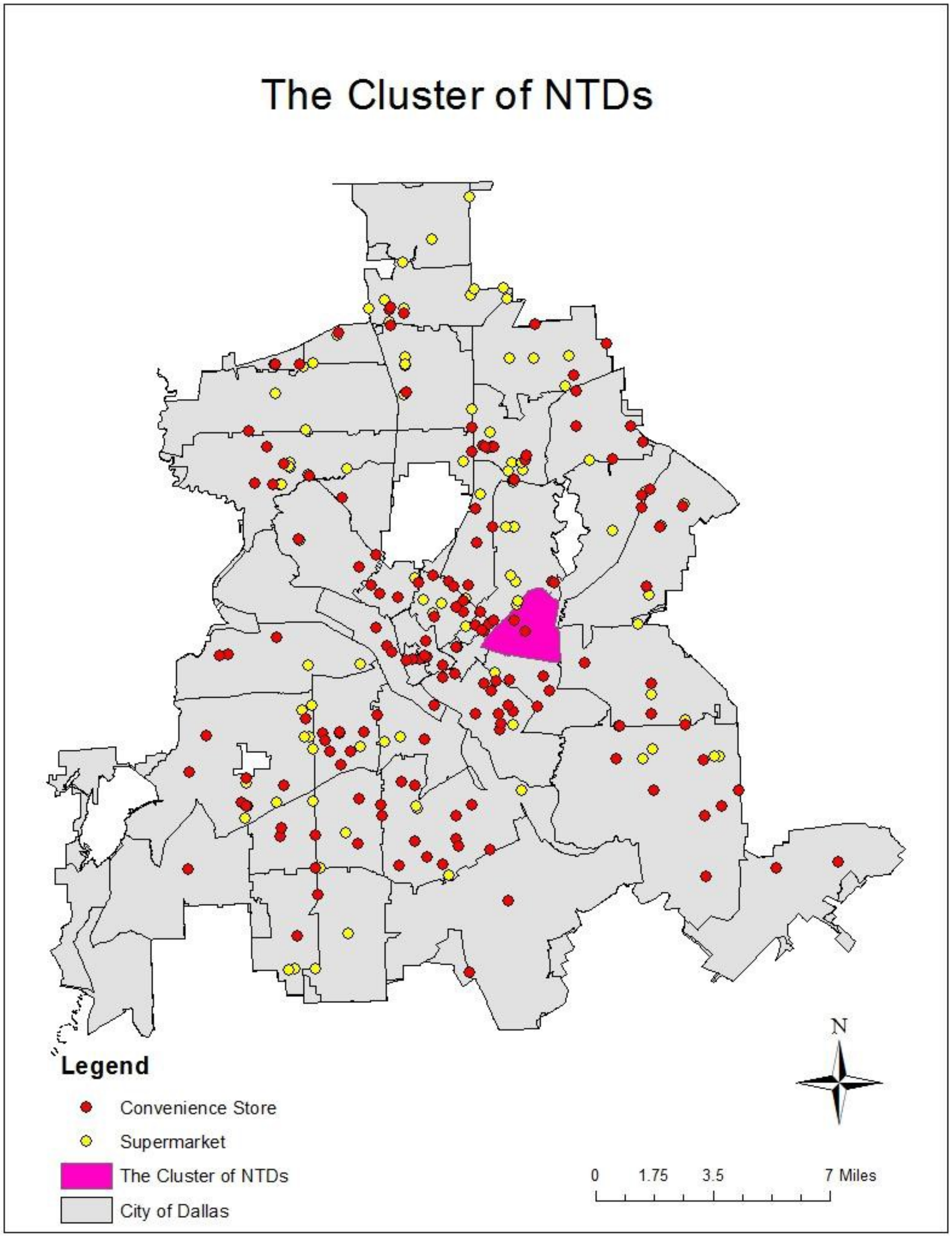

Figure 1. Cluster of NTDs.

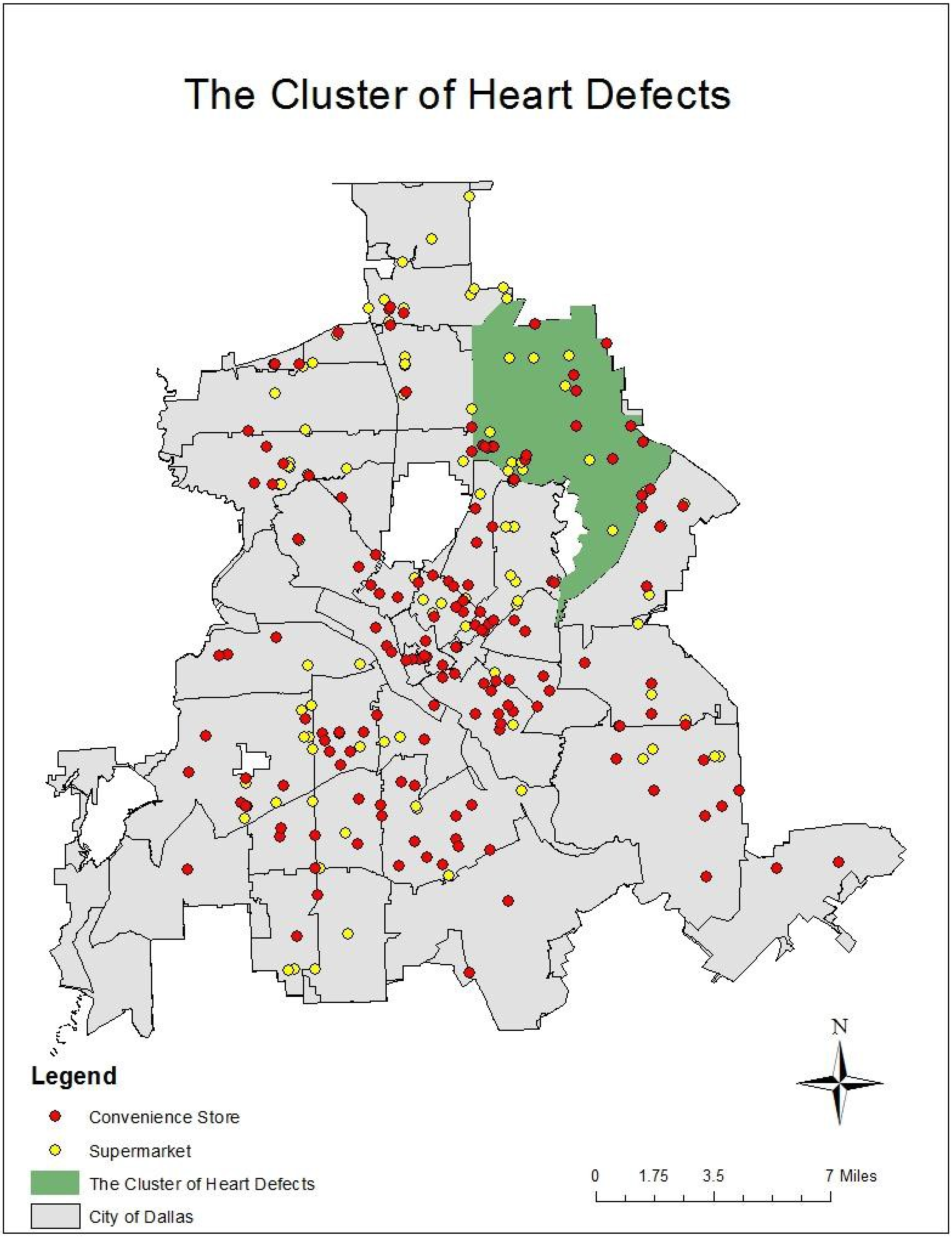

Figure 2. Cluster of heart defects.

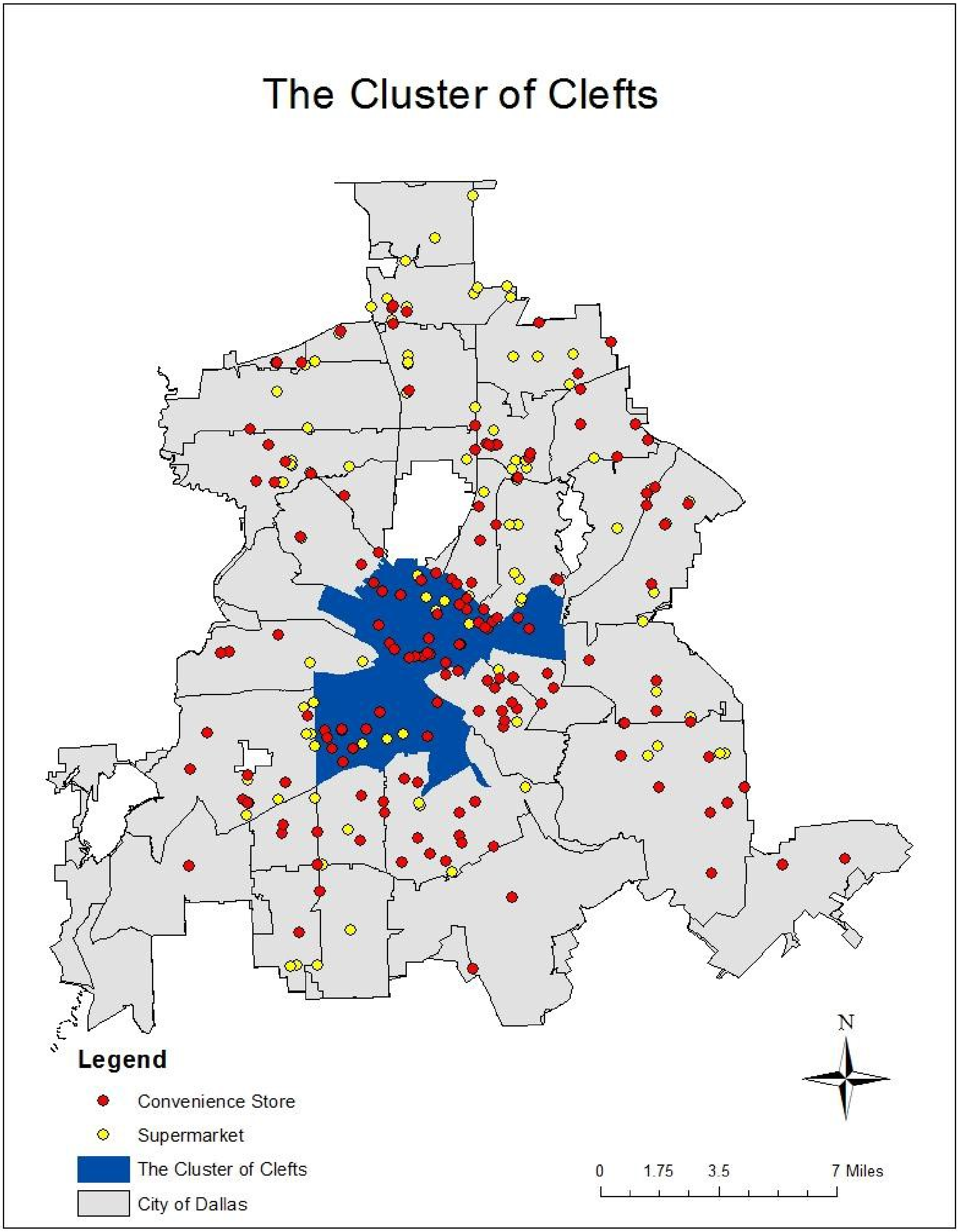

Figure 3. Cluster of clefts.

A zip-code within NTD cluster is extremely poor and contain high minority population especially Hispanics. In comparison to other two defects, heart defects tend to cluster in zip-codes with higher income areas and less minority population (except one zip-code). Clefts tend to cluster within extreme poor to household income (except one zip-code) with high rates of Hispanic population. Therefore, cluster for NTD occurs in vulnerable places with lower income and high minority population specifically Hispanics with no supermarkets. Cluster for heart defects mostly occurs in high income and predominantly white neighborhoods with many supermarkets. Clusters of oral clefts mostly occur in middle-class income with relatively high minority populations with many convenience stores.

Table 1

Cluster of NTDs

Zip-code	Income Level	White (%)	Black (%)	Hispanics (%)
75223	1.Extremely Poor	14.6	19.9	63.6

Table 2

Cluster of Heart Defects

Zip-code	Income Level	White (%)	Black (%)	Hispanics (%)
75218	3.High Income	75.1	4.8	17.0
75243	3.High Income	39.3	32.7	14.9
75231	1.Extremely Poor	27.9	27.1	40.3
75238	3.High Income	58.9	20.9	16.2
Mean	2.5	50.3	21.4	22.1

Table 3

Cluster of Clefts

Zip-code	Income Level	White (%)	Black (%)	Hispanics (%)
75246	1.Extremely Poor	27.8	12.6	55.9
75223	1.Extremely Poor	14.6	19.9	63.6
75201	2.Household Income	68.8	19.4	7.6
75202	2.Household Income	54.0	32.7	8.9
75208	1.Extremely Poor	22.5	4.2	71.6
75204	3.High Income	37.9	11.6	44.8
75203	1.Extremely Poor	3.9	35.3	59.8
75207	2.Household Income	43.1	37.4	17.9
75226	2.Household Income	37.9	11.5	48.5
75219	3.High Income	41.4	8.1	41.5
Mean	1.8	35.2	19.2	42.0

Proximity Network Detection

With slight varieties among birth defects, median proximity to convenience stores could be up to approximately 15 minutes and supermarkets up to approximately 20 minutes, both being able to be defined as walking distances from mothers' residences. Median distances to both supermarkets and convenience stores are the closest among clefts and the furthest among heart defects, however, there is no dramatic differences among three conditions.

Table 4

Median of Proximity to Stores from Each Defect (Meters)

	Cleft (N=349)	Heart (N=2379)	NTD (N=113)
Supermarket	1114	1429	1340
Convenience Store	1030	1128	1094

Bivariate K Function

The graphs below displays the results of bivariate K function analyses. The value of K function (shown on the y-axis) is indicative of the expected number of supermarkets or convenience stores within predefined distances from mothers’ residences with each birth defect (shown on the x-axis). The solid line represents the observed value of K function (i.e. the K function as determined by the observed data points). The dashed lines represent the theoretical bounds value of the K function under the assumption of no spatial dependence between stores and birth defects. The bounds were determined by simulating 999 points patterns of crime based on the assumption of complete spatial randomness (CSR). The dashed red and green lines represent the upper and lower bounds of the 95% confidence interval.

The observed values of the K function in graphs falls above the 95% interval, indicating a clustering of both supermarkets and convenience stores in close proximity to all NTDs, heart defects, and clefts. More specifically, all clusters are only evident at closer distance thresholds (~<5000m) and turn to random at further thresholds (~>5000m). In addition, both supermarkets and convenience stores are most likely to cluster at approximately 2000 meters from mothers’ residences with all birth defects, which is up to approximately 25 minutes walking distances away. However, concentrations of clefts stay borderline cluster over the all different distance thresholds.

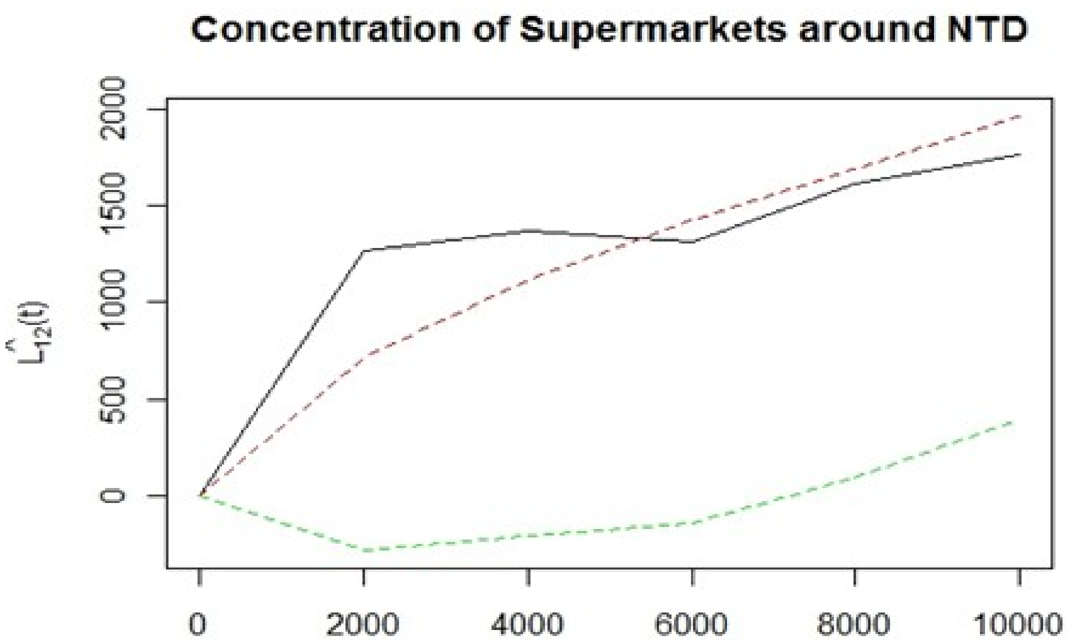

Figure 4. Supermarkets over multiple distance thresholds from NTDs.

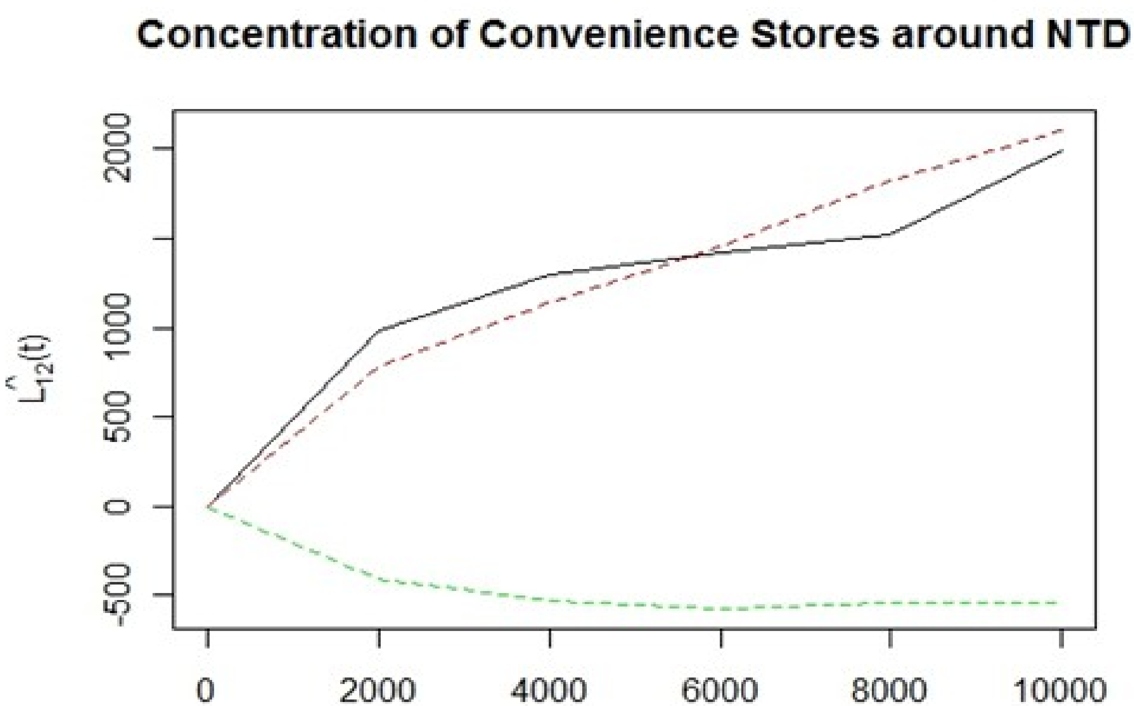

Figure 5. Supermarkets over multiple distance thresholds from NTDs.

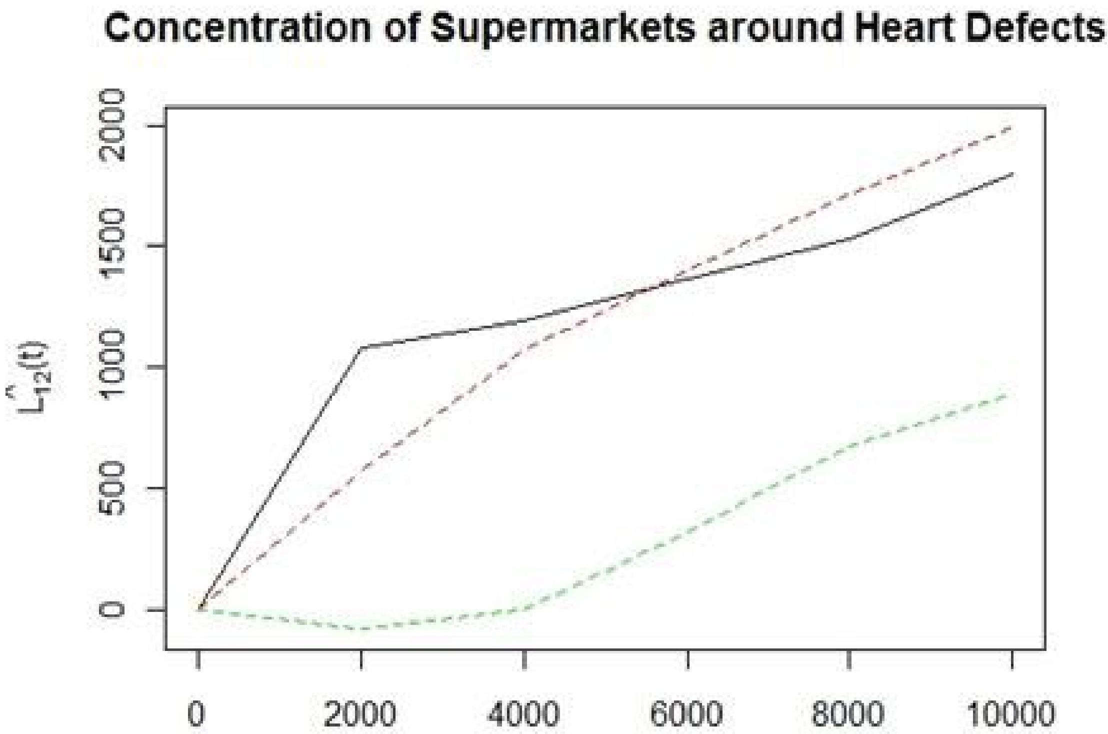

Figure 6. Supermarkets over multiple distance thresholds from heart defects.

Figure 7. Convenience stores over multiple distance thresholds from heart defects.

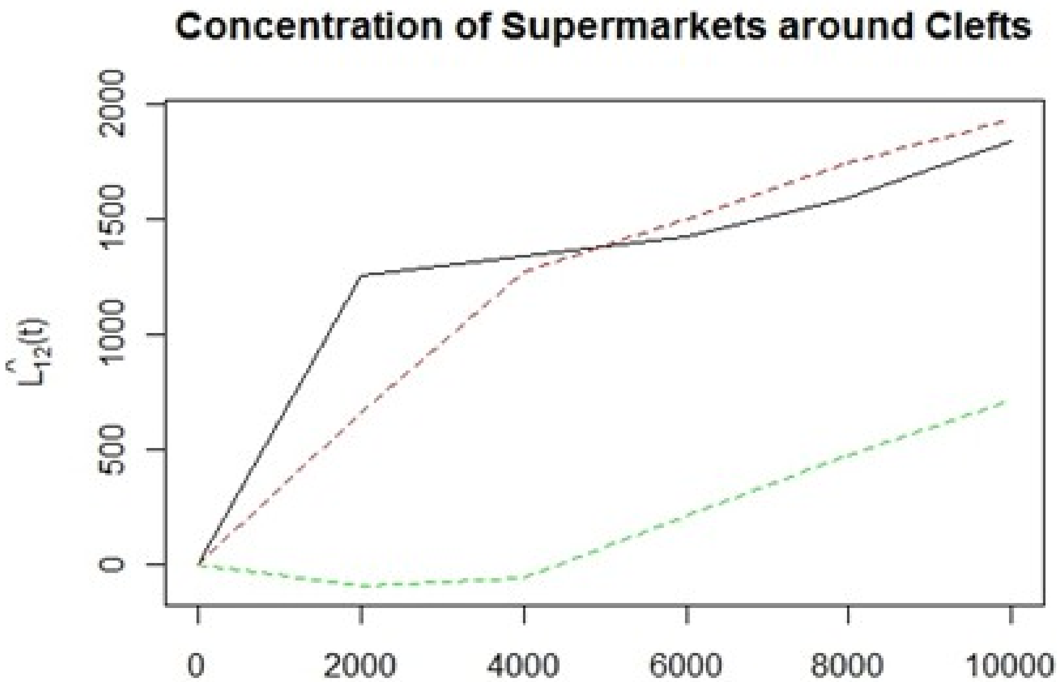

Figure 8. Supermarkets over multiple distance thresholds from clefts.

Figure 9. Convenience stores over multiple distance thresholds from clefts.

CHAPTER 7

DISCUSSION AND CONCLUSION

Discussion

Researchers have established the extent to which the nutritional quality of low-income consumers' diets could be shown to be related to the quality of access to retail provision of healthy food items such as fruits and vegetables (Wrigley, Warm, & Margetts, 2003). More specifically, improvement of unhealthy habits among low-income population by geographic intervention of retail-provisions has been confirmed in a Leeds, British city. Thus, improving geographic access to healthy foods, such as by locating a major grocery store in a food desert area, a major retail provision intervention on diet in a "'food deserts" has been suggested to be the potential to reveal bridge of the missing links between poor geographical access to healthy food vendors, compromised diets/undernutrition, and poor health outcomes, specifically nutrition-related birth defects in this study (Wrigley, Warm, Margetts, & Whelan, 2002).

Nevertheless, it is emphasized that food retail is only one component of various factors that affect how people eat and, more fundamentally, their nutrition status. The supply of healthy food will not suddenly change because the definitions of accessibility can be broad and very complicated. For example, financial, transportation, and cultural barriers can influence accessibilities. In Dallas where the majority of households with average incomes own cars, a sense of accessibility can change dramatically, depending on having a car or not. In the study, median distances to both supermarkets and convenience stores are the closest among clefts and the furthest among heart defects. However, this does not mean that mothers of infants with heart defects have the lowest access to stores because accessibility can vary depending on different factors such as income status and the following transportation availabilities. In fact, cleft clusters are detected mostly within low to middle class income with predominantly Hispanics neighborhoods, compared to heart defect clusters are detected mostly within relatively high income with predominantly white neighborhoods. The change of accessibility by transportation can be a little more intense for supermarkets, compared to convenience stores, due to larger median distances from mothers' residences, and this pattern applies to all three birth defects in the study.

As a cultural factor, the proportion with low dietary folic acid intake is significantly higher in Black and Hispanic women than in White women (Canfield, Anderson, Waller, Palmer & Kaye, 2002). More specifically, in Texas where the Hispanic population is higher than most other states, both White and Hispanic mothers are equally likely to recall receiving postpartum advice to use folic acid, but Hispanic women are much less likely to use folic acid (Canfield, Annegers, Brender, Cooper & Greenberg, 1996). This might be more largely attributable to a lack of nutrient fortification in Hispanic food rather than proximity or concentration of healthy food vendors. Thus, the conclusion supports the statement that there is no magic bullet for improving nutrition status that can further reduce nutrition-related birth defects by simply providing healthy food vendors within walking distances and emphasizes the importance of ecological approaches including socioeconomic factors such as income and race/ethnicity and related cultural and transportation factors.

Conclusion

First, spatial clusters of all three nutrition-related birth defects (NTD, heart defects, and oral clefts) exist, suggesting possibilities of spatial factors. Second, our expectation, based on the place vulnerability theory, that clusters occur more in vulnerable places, can be concluded as most accurate for NTDs when vulnerable places are considered as ones with lower income and high minority population specifically Hispanics with no supermarkets. The theory moderately applies to the cluster of oral clefts that occurs in middle-class income with relatively high minority populations with many convenience stores. However, it does not apply to heart defects and lower geographical access to healthy foods as an indicator of vulnerable places.

In shifting focus from clusters to the entire study area, the City of Dallas, median proximity to convenience stores could be up to approximately 15 minutes and supermarkets up to approximately 20 minutes with slight differences among three birth defects. Furthermore, high concentration of both supermarkets and convenience stores are observed within 25 minutes-walk from mothers' residences of infants with all nutrition-related birth defects. Therefore, supermarkets that include nutrients-fortified food products and diets that include recommended multiple nutrients are shown to be spatially reachable as median to mothers of infants with nutrition-related birth defects as well as convenience stores that include the majority of unhealthy processed foods that contain very few nutrients.

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