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In examining risk for Type 2 Diabetes Mellitus (T2DM) in Fort Worth elementary schools, the investigator answered the following questions: What is the geographical distribution of risk for T2DM in Fort Worth elementary schoolchildren? How is that related to the prevalence of obesity? To what extent is the spatial concentration of fast food restaurants a factor in the risk for diabetes and obesity prevalence in this population? The investigator also makes policy recommendations regarding the prevention of diabetes in children. Statistical and spatial analysis of data, provided from a previous study at UNTHSC that assessed overweight and risk for T2DM in elementary school children in the Fort Worth Independent School District, was used to assess the association between risk of diabetes in children and proximity to fast food restaurants. Geographic Information Systems (GIS) analysis was applied to the data to determine if such an association could be elucidated.

THE GEOGRAPHY OF THE RISK FACTORS FOR TYPE 2 DIABETES IN

FIFTH-GRADE SCHOOLCHILDREN IN FORT WORTH, TEXAS:

SPATIAL ASSOCIATIONS WITH OBESITY AND

FAST FOOD RESTAURANTS

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THE GEOGRAPHY OF THE RISK FACTORS FOR TYPE 2 DIABETES IN FIFTH-GRADE SCHOOLCHILDREN IN FORT WORTH, TEXAS: SPATIAL ASSOCIATIONS WITH OBESITY AND FAST FOOD RESTAURANTS

THESIS

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CHAPTER 1

INTRODUCTION

In examining risk for Type 2 Diabetes Mellitus (T2DM) in Fort Worth elementary school districts, the investigator attempted to answer the following questions: (a) What is the geographical distribution of risk for T2DM in Fort Worth elementary schoolchildren? (b) How is that risk related to the prevalence of obesity? (c) To what extent is the spatial concentration of fast food restaurants a factor in the risk for diabetes and obesity prevalence in this population? From the conclusions deriving from analysis of these factors, the investigator also makes policy recommendations regarding the prevention of diabetes in Texas.

Statistical and spatial analysis of data provided from a previous study, led by Dr. Ximena Urrutia-Rojas at the University of North Texas Health Science Center, that assessed overweight and risk for T2DM in elementary school children in the Fort Worth Independent School District (FWISD), was used to assess the association between risk of diabetes in children and proximity to fast food restaurants (Urrutia-Rojas et al., 2002). Risk for T2DM in this population of children was determined using the ADA guidelines for children (American Diabetes Association 2000 Mar). Geographic Information Systems (GIS) analysis was applied to the data to determine if such an association could be elucidated.

Statement of Purpose

The Scope and Significance of the Problem. Diabetes has become one of the most serious health problems globally, in the United States, and in Texas. In 2000, nearly 150 million adults around the globe and approximately 17 million people in the United States--6.2 percent of the population had diabetes (Davlin, 2003). Even more disturbing, diabetes prevalence in the US increased 61% over the last ten years—an outrageously high rate that if maintained, will nearly triple the number of affected adults by 2050 (Campbell, 2003 Jul-Aug). In Texas, where diabetes is the sixth leading cause of death, an estimated 1.3 million people have diagnosed diabetes, and an additional 343,000 Texans are estimated to have undiagnosed diabetes (Texas Diabetes Council, 2005).

The incidence rate of Type 2 diabetes, previously known as "adult-onset diabetes," is rising at an alarming rate among children, a population that is seeing a concurrent increase in the prevalence of obesity, a known risk factor for diabetes. In Texas, 35% of school-age children are considered overweight or obese (Texas Diabetes Council, 2005). These children are likely to retain their overweight/obese status as they move into adulthood (Serdula et al., 1993 Mar).

The condition of obesity is inter-related with the behaviors of physical activity and diet. Increasing sedentary habits and lowered rates of physical activity among children and adolescents have contributed to increased obesity rates. More hours of television viewing and game playing, as well as "obesegenic" environments, that is, lack of parks, trails, biking and walking routes between home and school, have supported positive energy balances in youth (Hohepa, Schofield, & Kolt, 2004).

An increasing proportion of American children's food intake consists of fare from "fast food restaurants." This type of restaurant now constitutes a "dominant dietary pattern, with a current estimate of about 247,115 restaurants in the USA" (Pereira et al., 2005 Jan 1-7). Children now are eating about five times more fast-foods than when their parents were children, increasing from 2% of total diet in the 1970s to 10% in the 1990s.

Diabetes Description and Burden. Diabetes mellitus is a metabolic disorder in which either the pancreas fails to produce enough insulin to transport blood glucose into cells, or the cells fail to use insulin properly. Three main types of diabetes exist: Type 1, an autoimmune disease; Type 2, where the body is resistant to insulin; and Type 3, gestational, which occurs only during pregnancy. Type 2 diabetes mellitus (T2DM) accounts for 90-95 percent of all diabetes cases (National Diabetes Information Clearinghouse, n.d.).

While the etiology of diabetes continues to be investigated, some probable pathways have been elucidated. Certainly, overweight and obesity, as measured by BMI, are well established as positive associations leading to T2DM (American Diabetes Association, 2000; Rosner, Prineas, Loggie, & Daniels, 1998). In 2000 the American Diabetes Association published a consensus of risk factors for T2DM (American Diabetes Association, 2000), which include:

- obesity—up to 85% of diagnosed children are classified as overweight or obese;
- family history of diabetes—74-100% of diagnosed children have a first- or second-degree relative with T2DM.
- acanthosis nigricans—a dermatological condition characterized by hyperpigmentation is commonly found in children with T2DM.

Although physiological characteristics such as family history of diabetes, genetics, hypertension, high or low blood sugar, and race/ethnicity have been established as risk factors or risk markers for T2DM, various behavioral risk factors have also been identified that lead to a diagnosis of diabetes, including diet and minimal or no physical activity (Harris, 1995).

Research Questions and Hypotheses. Geographic Information Systems (GIS) analysis and findings from the literature were applied to answer questions relating neighborhood characteristics to potential exposure to fast food:

- What is the average distance traveled by children in the study areas to patronize fast food restaurants?
- Are there variations in exposure to fast food across the 17 school areas?
- Does household income range within these neighborhoods affect the amount of fast food consumed by the study population? Are fast food sales volumes higher in some neighborhoods than in others, and can those figures be associated with average neighborhood incomes?

Two hypotheses were investigated in this study:

1. The spatial prevalence of obesity in Fort Worth schoolchildren coincides with spatial patterns of risk for T2DM in this population and with geographical concentrations of fast food restaurants in the Fort Worth Independent School District.

2. Risk for T2DM in this group of children is higher in areas with higher concentrations of fast food restaurants. Areas with more fast food restaurants will exhibit higher levels of diabetes risk in this group of children.

Importance of This Study

Serious health and economic consequences result from diabetes. Approximately $132 billion is spent annually in the U.S. on diagnosing and treating diabetes (Bertoni, Kirk, Goff, & Wagenknecht, 2004 May). Complications of diabetes contribute to co-morbidities and impaired life expectancy. Cardiovascular disease, stroke, hypertension, blindness, kidney disease, amputation, and an estimated loss of between eleven and fourteen years of life may result from diabetes (Bazzano, Serdula, & Liu, 2005 Oct). In fact, diabetes ranks as the sixth leading cause of death in Texas, and as the fourth leading cause of death for Hispanics and African Americans. The mortality rate in Texas from diabetes is about 31.4 per 100,000, which in 2002 yielded a staggering 5,650 deaths directly attributable to diabetes, with an additional 17,423 deaths indirectly linked to this disease (Aye & Levitsky, 2003 Aug). With Type 2 diabetes occurring more frequently in children, these sequelae have even greater opportunity to develop, thus compromising the health of Texans at younger ages than has heretofore been typical. An understanding of the "upstream" behavioral risk factors is essential for the prevention and control of this chronic disease.

Limitations

One limitation is that this study population did not undergo clinical examination to determine clinically risk of T2DM; only the presence or absence of risk for T2DM was assessed based on the ADA guidelines. Therefore, this study could not draw conclusions about the prevalence of diabetes *per se*, but only about the risk for diabetes. Another limitation is that these subjects were not specifically asked about frequency of use of fast food restaurants. Tying this variable to the prevalence of risk for diabetes and obesity, therefore, was by inference from area sales volumes and locations of fast food restaurants.

Definitions of Terms

Body Mass Index (BMI). Body Mass Index (BMI) is found by dividing a person's weight in pounds by height in inches squared, multiplied by 703 ((lbs./inches^2) x 703).

Overweight. Children with a BMI $\geq$ 85th percentiles but $\leq$ 94.99th percentile, for age and sex, were classified as overweight, and those with a BMI $\geq$ 95th percentile were classified as obese. Since overweight or obesity (BMI $\geq$ 85th percentiles) is the main criteria for selecting children at risk, the two categories were combined in this study (American Diabetes Association, 2000 Mar; Rosner, Prineas, Loggie, & Daniels, 1998 Feb).

Risk for Type 2 Diabetes Mellitus. Risk for T2DM was defined from two variables available from the DREAMS study, family history of diabetes and presence or absence of acanthosis nigricans. These variables were treated independently in this study, but, when considered in combination, they are regarded as reliable and prognostic indicators for contracting T2DM (Burke, Hale, Hazuda, & Stern, 1999; Urrutia-Rojas et al., 2002).

Exposure. Exposure in this study was defined as the relative proximity of children's residences and schools to locations of fast food restaurants.

Fast food restaurants. In this study, fast food restaurants were defined, per the U.S. Economic Census, as "Limited Service Eating Places," which include establishments assigned the North American Industry Classification System (NAICS) code of *7222* (U. S. Census Bureau, 2004).

Income range. Median household income for block groups within the study populations' neighborhoods were retrieved from the U. S. Census Bureau. Income ranges were determined according to natural breaks from the data.

CHAPTER 2

LITERATURE REVIEW

Behavioral Risk Predictors for Diabetes

Two important categories of risk factors were investigated in this study: overweight/obesity and diet.

<u>Risk Factor No. 1: Overweight and Obesity</u>. Diabetes and obesity are closely related. The Agency for Healthcare Research and Quality (AHRQ) in January 2004 released a *Statistical Brief* that all but stated a causal relationship between obesity and diabetes. According to this report, 79% of diabetics adults in 2001 were overweight or obese, compared with about 58% of non-diabetics (Stagnitti, 2004). Obesity itself is increasingly contributing to life years lost and disease status. Haslam and James (2005) describe excess bodyweight as the "sixth most important risk factor contributing to the overall burden of disease worldwide."

The concentration of the obesity epidemic in children has been astounding: In Texas, 35% of school-age children are considered overweight or obese. Almost twice as many Texas adults, 63%, are in this category (Texas Diabetes Council, 2005).

<u>Risk Factor No. 2: Diet</u>. Fast-food restaurants have become a staple of American society. They now constitute a "dominant dietary pattern, with a current estimate of about 247,115 restaurants in the USA" (Pereira et al., 2005). Children now are eating about five times more fast-foods than when their parents were children, increasing from

2% of total diet in the 1970s to 10% in the 1990s. An individual's daily caloric requirements often can be consumed in one meal from a fast-food restaurant.

A complex network of factors has fostered an environment that impedes healthy weight maintenance. Among these, according to an Institute of Medicine report (2005), are increased reliance on high-calorie and high-fat "convenience" foods and decreased use of fresh vegetables and nutritious foods. An ecological study in 23 San Diego middle schools showed that weekly *a la carte* sales of vendor-and school-prepared fast food constituted more than 16,000, or about 26 percent out of a total of about 62,000 items. These items were all high in fat, averaging between 9 and 16 grams of fat per item (Zive et al., 2002). While these authors did not collect data on the weight status of the children attending these schools, they did posit a causal relationship between fast food and diet quality. They also cited other studies that observed a predictive association between fast food consumption and dietary fat and positive energy balances (Cusatis & Shannon, 1996; French, Story, Neumark-Sztainer, Fulkerson, & Hannan, 2001; McNutt et al., 1997).

Lin et al. (2001), reporting on the USDA's Economic Research Service's data on the respective contributions of food sources to children's total caloric intake, found that fast foods are contributing more calories to children's diets: from 1977 to 1996, fast food increased from 2 percent to 10 percent of total calories consumed by children.

Little research has been aimed at the possible association between fast food consumption and the risk of obesity and T2DM. However, a study in 2004 of 6,212 children, from a nationally representative sample, delivered the surprising conclusion that nearly one-third of U. S. children eat fast food every day, and that this consumption adds approximately six pounds per year, increasing the risk of obesity (Bowman, Gortmaker, Ebbeling, Pereira, & Ludwig, 2004). Children who ate fast food had an average daily caloric intake of 187 more calories, and they had a greater proportion of fats, sugars, and carbohydrates and a lower proportion of fruits and non-starch vegetables in their diets, than did children who abstained from fast food.

One of the first studies to provide evidence for a causal physiological link between fast foods and obesity was published in 2003. Prentice and Jebb found that the average energy densities from well-known fast food restaurants were much higher than the energy density of a "normal" African diet, and that "it is virtually impossible to select a combination of items that yield even a moderate energy density." The team stated that "the exceptionally high energy density of most modern fast foods challenges [humans'] appetite control systems with conditions for which they were never designed" (Prentice & Jebb, 2003). And Pereira et al. (2005), in a longitudinal prospective study in young (ages 18-30) adults, reported a strong association between frequent consumption of fast-foods and increased bodyweight and insulin resistance, especially among more sedentary subjects.

Prior to these studies, fast food companies had already taken defensive action. In the wake of adverse publicity by popular media, such as the bestselling *Fast Food Nation* (Schlosser, 2001) and the well-known movie, *SuperSize Me* (Spurlock, 2004), and of litigation against McDonald's, which alleged negligence in knowingly selling foods that were high in fat, cholesterol, and sugar, the U. S. National Chamber of Commerce released a report that repudiated any relationship between fast foods and their possible contribution to obesity (Buchholz, 2003). The report, as well as industry press information, point to additions to the menus of fast food restaurants of more healthful offerings, such as salads, and vegetables. In 2004, the National Restaurant Association presented its view of the industry's "proactive" efforts to add more healthful menu items and to promote healthy lifestyles before the U. S. Senate's Commerce Subcommittee (Culpepper, 2004).

Sales at fast food restaurants have ballooned more than 917 percent over the past thirty years, from \$16.1 billion in 1975 to \$163.7 billion in 2005. Fast food restaurant sales in 2005 alone jumped seven percent over the previous year, more than doubling the annual average rate of growth (Technomic, 2006).

The top ten fastest-growing fast food restaurants in 2004, according to one-year increases in sales volumes reported by Technomic, were:

1. McDonald's
2. Starbucks
3. Subway
4. Dunkin' Donuts
5. Wendy's Old Fashioned Hamburgers
6. Sonic Drive-Ins
7. Taco Bell
8. Quiznos Sub
9. Panera Bread
10. Pizza Hut

Fast food restaurants in the United States number between 230,000 (U. S. Economic Census, 2005) and 280,000 (Austin et al., 2005 Sep). They now outnumber "table service restaurants" by about 33,000. Subway leads in the greatest increase in number of stores with 1,411 units added nationwide from 2003-2004, followed by Starbucks, Quiznos Sub, Dunkin' Donuts, Sonic Drive-Ins, Wendy's, Panera Bread, and Chipotle. (Although ice cream stores were not considered in this study, it is interesting to note that two chains in this category, Cold Stone Creamery and Ben & Jerry's, experienced a far greater increase in their total number of retail outlets than did all other types of limited service food establishments, with 65 percent and 40 percent increases in new stores, respectively).

In Texas, the number of fast food restaurants (NAICS code 7222) grew from 14,823 in 1997 to 16,538 in 2002, an increase of 11.6 percent, while sales volumes increased approximately 55.6 percent, from approximately $11.7 billion to $18.2 billion during that period. The number of fast food restaurants in Tarrant County increased from 1,156 in 1997 to 1,302 in 2002, an increase of 12.6 percent; sales volumes in Tarrant County increased from $735.4 million in 1997 to $947.2 million in 2002, an increase of 28.8 percent (U. S. Economic Census, 2005). The census of Fort Worth limited-service eating places stood at 446 in 2002, with sales of about $316.5 million; the 1997 Census did not segregate Fort Worth as a unit, so comparative census data for that year are not available.

The burgeoning fast food market corroborates the findings of several studies: Americans are growing increasingly dependent on fast food for their meal choices. According to NPD Group's 20th annual *Eating Patterns in America*, "ninety-two percent of take-out lunches come from fast food restaurants today, and 92 percent of individuals consume some form of 'ready-to-eat' foods in the home on a daily basis" (NPD Group, 2005). Sales at fast food restaurants now account for nearly 30 percent of the $500 billion U. S. restaurant industry (NPD Group, 2005). Consumer spending in fast food restaurants has increased since 2002 at an annual rate of 6.8 percent, compared with an annual 4.7 increase in spending at full service establishments (Austin et al., 2005 Sep). The U. S. Department of Agriculture's Economic Research Service forecasts an increase of six percent in expenditures on fast food by Americans over the next fifteen years (Stewart, Blissard, Bhuyan, & Nayga, 2004).

A significant proportion of these expenditures is spent on meals for children (Bowman et al., 2004). Fast food consumption by children aged 2-17 increased from 2 percent in 1977-78 to 10 percent in 1994-98 (Lin, Guthrie, & Frazao, 2001). Children are a primary market target of the food industry, which recognizes their strong influence on parents' spending choices and their potential as future customers (Austin et al., 2005 Sep; Gardner, 1997). "Cradle-to-grave marketing" has long been practiced by food industry giants, such as McDonald's and Coca-Cola. School cafeterias were found to be marketing sites for brand-name foods, which are served, advertised, and branded on "educational" materials. Levine (1999) found that fast foods have become increasingly present at elementary schools: "Approximately 9% of elementary schools participating in the school lunch program offered brand-name fast foods to students during the 1995-

1996 school year. The three most popular vendors were Pizza Hut, Domino's Pizza, and Taco Bell."

In addition to the conspicuous presence of fast foods inside schools, there is also evidence that stand-alone fast food restaurants are being deliberately placed near schools. A recent study published in the *American Journal of Public Health* (2005) found significant concentrations of fast food restaurants within short walking distances of schools in Chicago. "The median distance from any school to the nearest fast-food restaurant was 0.5 km, indicating that in half the city's schools, students need to walk little more than 5 minutes to reach a fast-food restaurant. Nearly 80% of schools in Chicago had at least 1 fast-food restaurant within 800 [meters] (Austin et al., 2005 Sep).

Some studies (Goodman, Slap, & Huang, 2003 Nov; Wang, 2001 Oct; Zhang & Wang, 2004 Mar) have reported strong associations between obese children and lower socioeconomic status. A spatial study released by the Urban Institute showed that "children from areas with very low median income are the most likely to be obese; the odds of obesity relative to children from areas with upper income are 1.55 (95 percent confidence interval: 1.27-1.90)" (Kandris & Liu, 2003). A later study by Drewnowski and Specter (2004) corroborated this finding and posited the relatively low cost of energy-dense foods as a contributing factor. These results are supported by the findings of the USDA's Economic Research Service, that "low-income households spent significantly [about 20 percent] less on fruits and vegetables than higher income households (Blisard, Stewart, & Jolliffe, 2004). Since many fast food menu items are high in fat and calories, it may be inferred that residents in lower SES areas would patronize fast food restaurants for a portion of their dietary needs. It may further be suspected that fast food restaurants tend to be located in lower income areas.

CHAPTER 3

METHODOLOGY

Population and Sample

The study design is a secondary data analysis of a cross-sectional study of a school-based sample of fifth grade elementary school children in Fort Worth, Texas performed in spring of 2000 (Urrutia-Rojas et al., 2002). The study population included 1,076 fifth graders from 17 schools, aged 8 to 13 years, who were assessed, by physical examination for anthropomorphic and physiological characteristics, for risk for T2DM according to ADA guidelines for children. The schools were originally selected as being representative of neighborhoods across Fort Worth.

Protection of Human Participants

The UNTHSC Institutional Review Board granted exempt status to this study on April 13, 2006. No human participants were included in this study, and no subject identifiers were included in the data released to this investigator.

Data Collection Procedures

Data recorded in the original study (Urrutia-Rojas et al., 2002) included age, date of birth, gender, ethnicity, height, weight, body mass index, systolic and diastolic blood pressure, reported family history of diabetes mellitus, acanthosis nigricans, "risk for T2DM," and eating and physical activity practices. The data elements used in this study were:

- risk for T2DM
- body mass index over 85th percentile;
- family history of diabetes
- presence or absence of acanthosis nigricans (AN)
- school identifiers
- school addresses

A list of 1,638 restaurants in Fort Worth was provided by the Fort Worth Public Health Department. Fast food restaurants, defined as "limited-service eating places" were identified by inspection of this list. The U. S. Economic Census codes restaurants as "limited-service eating places" according to the following definition:

> This industry group [7222] comprises establishments primarily engaged in providing food services where patrons generally order or select items and pay before eating. Most establishments do not have waiter/waitress service, but some provide limited service, such as cooking to order (i.e., per special request), bringing food to seated customers, or providing off-site delivery (U. S. Census, 2001).

All restaurants that were known or surmised to fall within this category were extracted from the health department list, yielding a total of 426 establishments.

Median household income data for the census tracts within each school's 1.5-mile catchment area were downloaded from the U. S. Census website (americanfactfinder.gov).

Data Analysis

Data analysis consisted of three phases:

1. Descriptive statistics—Frequency distributions and cross-tabulations were used to capture an overall description of the data. These calculations were applied to the independent variables of BMI $\geq 85^{th}$ percentile, family history of diabetes, presence or absence of AN, and income. The proportions of BMI $\geq 85^{th}$ percentile (BMIP), family history of diabetes (FHP), and presence/absence of AN (ANP) were calculated for each school.
2. Locational and GIS analysis-- Locational patterns of fast food restaurants and schools were examined. First, the mean and median distances from schools to fast food restaurants within the schools' catchment areas were calculated. Second, ArcGIS software was used to create 1.5-mile buffers around each school and then to calculate the number of fast food restaurants located within the buffers. Finally, the point distance from each school to each restaurant was figured in ArcGIS, and the "nearest neighbor" function within a spatial join was used to calculate average distances in order to determine which schools were closer to fast food restaurants.
3. Statistical analysis--The association of risk for T2DM with obesity and with proximity of fast food restaurants to children's schools and residences were assessed with correlation and linear regression.

By law, students' home addresses from the original data were required to be deleted before delivering to this investigator. Although exact residence addresses were not available, the schools' locations were used as a proxy for students' home sites, since students typically live in neighborhoods closely surrounding the schools they attend. "Consequently, the number and volume of sales of fast food restaurants in a particular school's catchment area is a measure of the exposure of children in the school to fast foods and can be a proxy variable for fast food consumption" (Joseph Oppong, personal communication, January 27, 2006).

The 17 schools are distributed across ten zip codes within the Fort Worth city limits, spanning an irregular area approximately 10 miles by 15 miles (see Figure 1). The catchment area of each school was estimated as a radius of 1.5 miles; this distance was selected because it encompassed both walking and short driving distances. In the Chicago study, 0.5 kilometers was used as the catchment area because this distance was considered to be within a "comfortable" five-minute walk (Austin 2005). However, walking is a predominant mode of transportation in an urban area such as Chicago, while the automobile is preferred in Texas. Therefore, the investigator chose 1.5 miles as a comparable comfortable driving distance. In addition, a wider radius of, for example, two miles, overlapped other schools' neighborhoods to such a degree that individual characteristics of each school would have been less distinguishable. On the other hand, a smaller radius would have excluded many fast food restaurants.

Neighborhoods falling within the catchment areas were captured at the census tract level, by which their demographic and economic characteristics were retrieved from U. S. Census data, available from American Factfinder (census.gov).

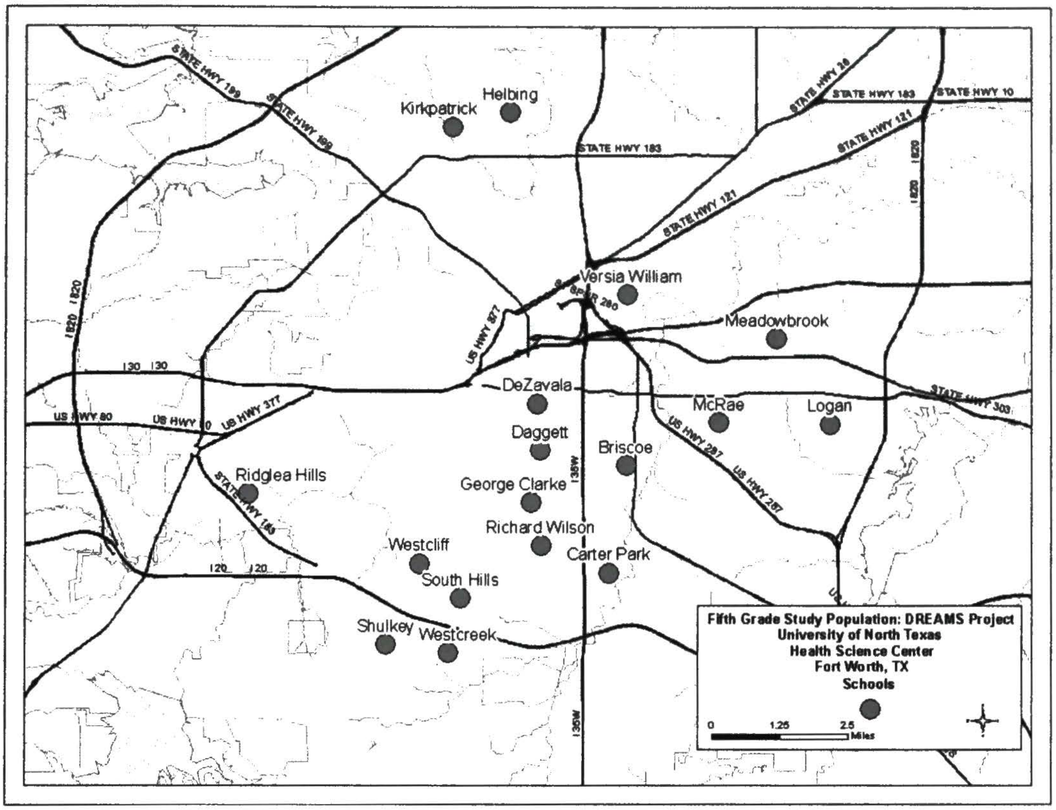

Figure 1. Study population area by ZIP code showing school locations.

Locations of fast food restaurants were plotted within the catchment areas as a layer of a chloropleth map. Geographic Information Systems (GIS) analysis and findings from the literature were applied to answer the previously-posed questions relating neighborhood characteristics to potential exposure to fast food.

The independent variables were:

1. Overweight/obesity
2. Family history of diabetes
3. Presence of acanthosis nigricans
4. Distance from schools and neighborhoods to fast food restaurants
5. Household income of neighborhoods

Summary

Each independent variable was compared spatially with the geographic distribution of the fast food restaurants in the 17 school areas. Correlation and regression were used to determine (1) whether a significant association can be discerned between each variable and the locations of risk of T2DM prevalence in Fort Worth schoolchildren and (2) the strength and direction of an association, if one exists.

CHAPTER 4

RESULTS

1. Descriptive statistics

The overall mean prevalence of overweight/obesity in this sample was 29.6 percent, and 54.2 percent had a family member who had been diagnosed with diabetes (FAM%). Nearly 16 percent of these subjects exhibited acanthosis nigricans (AN%) (Table 1). The proportions of BMI over 85th percentile (BMI %) within each school ranged from 13 percent (Ridglea Hills) to 38.6 (George Clarke).

NAME	BMI % Intra-school	BMI% Percentage of Total	FAM % Intra-school	FAM % Percentage of Total	AN % Intra-school
Briscoe	25.6	3.7	51.3	3.5	23.7
Carter Park	31.8	8.0	50.6	7.5	17.9
Daggett	23.6	8.3	58.4	9.1	12.6
DeZavala	30.4	6.5	47.1	5.6	13.0
George Clarke	38.6	4.1	58.1	4.4	15.9
Helbing	43.4	5.0	43.4	4.0	32.7
Kirkpatrick	17.1	3.3	42.9	2.6	8.6
Logan	36.0	2.3	48.0	2.1	32.0
McRae	35.3	8.0	57.6	8.6	18.1
Meadowbrook	32.3	5.8	58.1	6.3	15.0
Richard Wilson	27.0	5.9	57.1	6.3	12.7
Ridglea Hills	13.0	4.3	50.0	4.0	2.2
Shulkey	24.0	4.7	56.0	4.9	6.0
South Hills	33.0	9.9	63.5	11.5	10.5
Versia William	32.0	4.7	50.0	4.4	20.0
Westcliff	28.2	6.7	55.7	6.8	15.7
Westcreek	31.9	8.8	53.9	8.4	9.8
MEAN	29.6	5.9	54.2	5.9	15.7

= Lowest dispersion = Highest dispersion = Closest to median

Table 1. Inter- and Intra-School Prevalences of Risk Factors in Study Population

Comparing the contribution each school made to the population's overall BMI over 85th percentile showed that Logan, which had a relatively high intra-school prevalence of obesity (36 percent) compared to the other schools, contributed the lowest amount to the total high-BMI counts across all the schools. The highest BMI contributions came from Westcreek (8.8 percent and South Hills (9.9 percent), whose intra-school BMI over 85th percentiles were closer to the mean. Helbing (2.1 percent) and Versia William (2.6 percent) contributed the lowest percentages to the all-school proportions of family history of diabetes mellitus; it is interesting that Helbing had the highest proportion of intra-school obesity of all 17 schools (43.4 percent). South Hills contributed the highest amount of diabetes family history (11.5 percent).

How did the proportions of obesity and risk factors for T2DM compare with each other? From Table 1 we can see that South Hills was among the highest contributors in both categories: it contributed both the highest values for inter-school BMI and FAM, and it had the highest intra-school percentage of FAM. Similarly, Helbing, which had the highest intra-school obesity, also had the highest concentration of AN; and Ridglea Hills, which had the lowest intra-school obesity, also had the lowest concentration of AN. Kirkpatrick had the lowest inter-school BMI and low intra-school AN; its other scores were also in the low ranges. Schools that were close to the mean in one or two categories were also close to the mean in all other categories.

2. Geographic analysis

The catchment areas of the 17 schools fall athwart 21 census tracts. The average median household income of those census tracts whose areas appeared to overlap the schools' catchment by at least 50 percent was calculated. An average median household income was then assigned to each school (Table 1). The overall average median household income of all schools was $32,072, with a range from about $24,000 (Briscoe) to $48,000 (Shulkey).

Ninety-five percent of the addresses (n=426) for the identified fast food restaurants were matched in the ArcGIS catalog, (98 percent is considered to be the best U. S. Census code rating). Thirty restaurants were excluded either because their zip codes could not be verified or because they were located inside a mall, resulting in 395 fast food restaurants in Fort Worth included in the analysis.

Restaurants in the database included 35 brand-name chain restaurants, including Arby's, Subway, Taco Bell, and McDonald's. Subway is the most ubiquitous chain, with 40 stores in Fort Worth, followed by McDonald's with 21 locations, Jack in the Box (19), Whataburger (17), and Sonic (16) (Table 2). These restaurants serve such fare as hamburgers, fried chicken, pizza, submarine sandwiches, and french fries. These 35 chains comprised 65 percent of the restaurants in the database.

Name	No.
Subway Sandwich Shop	40
McDonalds	21
Jack In The Box	19
Whataburger	17
Sonic Drive In	16
Dominos Pizza	13
Wendys	13
Churchs	12
Taco Bell	12
Pizza Hut	10
Cici Pizza	8
Kentucky Fried Chicken	8
Taco Bueno	6
Chicken Express	5

Long John Silver	5
Quiznos	5
Arbys	4
Papa Johns Pizza	4
Schlotskys Deli	4
Wingstop	4
Boston Market	3
Chick-Fil-A	3
Dairy Queen	3
Grandys	3
Little Caesars Pizza	3
Potbelly Sandwich Works	3
Taco Cabana	3
Chipotle Mexican Grill	2
Perrottis Pizza	2
Burger King	1
Captain D's	1
Panera Bread	1
Pizza Inn	1
Popeyes	1

Table 2. Fast Food Restaurants in Fort Worth, Texas

The addresses of the 395 restaurants were compared with the school catchment areas; each restaurant address was assigned to one or more schools. Twenty restaurants fell outside the catchment areas, leaving a total *n* of 375 restaurants. ArcMap was then used to plot the restaurant locations within the school catchment areas (Figure 2).

The mean number of restaurants within schools' catchment areas is 22. The schools with the greatest numbers of surrounding fast food restaurants are Shulkey (39), George Clarke (36), and Daggett and Richard Wilson (34 each). Shulkey is the farthest southwest of all schools, while the other three, whose catchment areas all overlap with each other, are in the southwest quadrant along a north-south line parallel and about one mile west of Interstate-35. The fewest number of fast food restaurants lies within the catchment areas of Briscoe (5) and Versia William (11); these schools are more centrally located, but are to the east of I-35 at about a one-mile distance. South Hills also captures only 11 restaurants, but its location is to the west of I-35 and overlaps Shulkey and Westcreek.

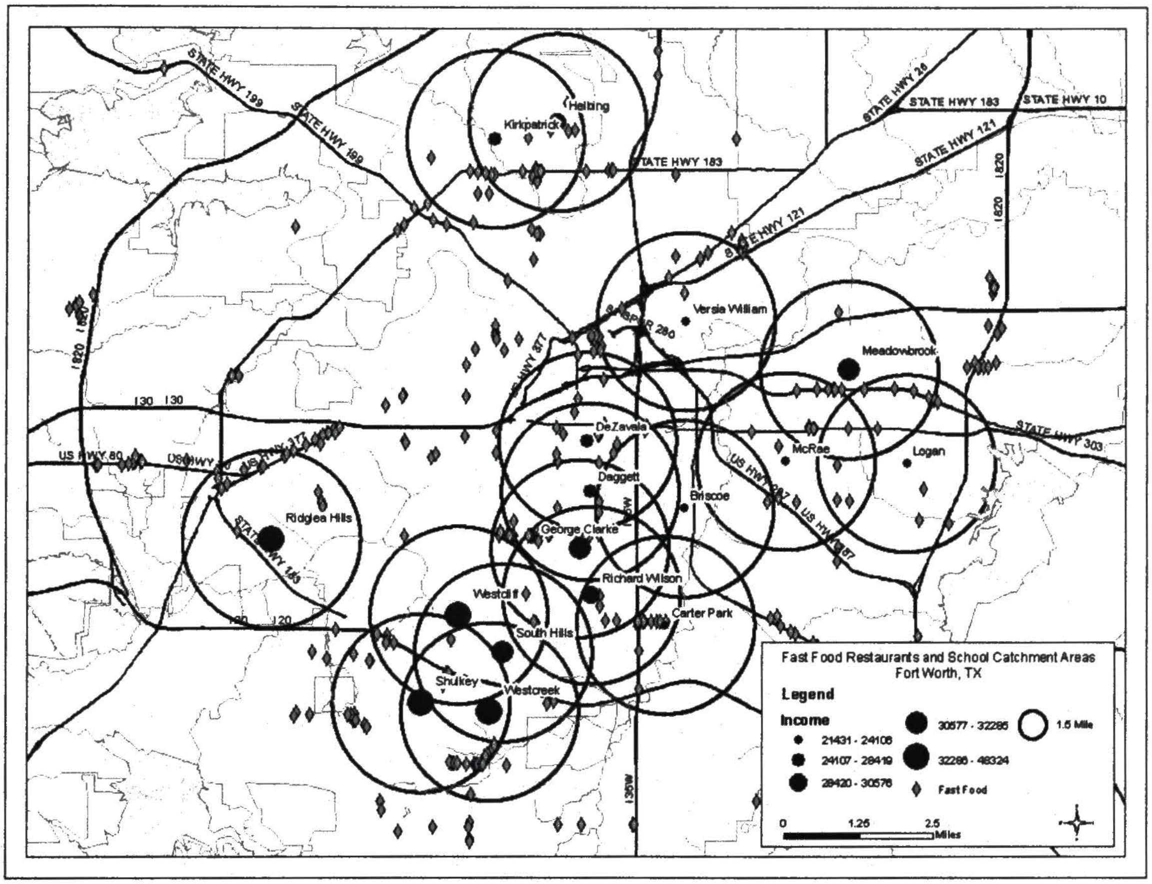

Figure 2. Fast Food Restaurants and Median Household Income Within School Catchment Areas

The independent variables of BMI, family history, and income were joined to the restaurant data and plotted with ArcGIS. Graduated symbols on the maps indicate the class ranges (Figs. 1-5).

In order to draw meaningful conclusions on the possible effect of fast food on the independent variables, the schools were stratified according to:

1. Numbers of fast food restaurants: low=0-15; medium=16-30; high=31-45.

   Five schools were considered low in number of fast food restaurants: Briscoe, Versia William, South Hills, Westcliff, and Logan. Four schools fell into the "high" category: Richard Wilson, Daggett, George Clarke, and Shulkey.
2. Income levels: low=$20,000-29,999; medium=$30,000-39,999; high=$40,000-49,999.
3. BMI over 85th percentile: low=13.0-23.9%; medium=24.0-34.9%; high=35.0-46.0%.
4. Family history of diabetes mellitus: low=42.0-48.9%; medium=49.0-55.9%; high=56.0-64%.
5. Acanthosis nigricans (AN) presence or absence: low=2.0-11.9%; medium=12.0-21.9%; high=22.0-33.0%

The stratified variables are depicted in Table 3.

Eight schools were in low-income neighborhoods: Briscoe, Versia William, Logan, Carter Park, DeZavala, Kirkpatrick, and Daggett. Four schools were in high-income neighborhoods: Westcliff, Ridglea Hills, Westcreek, and Shulkey.

School Name	Rest. Class: Low=0-15 Medium=16-30 High=31-45	Income: Low (Li) Medium (Mi) High(Hi)	BMI ≥ 85^{th} P.: Low (Lb) Medium (Mb) High (Hb)	Family History DM: Low (Lf) Medium (Mf) High (Hf)	Acanthosis Nigricans: Low (a) Medium (a) High (a)
Briscoe	Low	21,431 (Li)	25.6 (Mb)	51.3 (Mf)	23.7 (Ha)
Versia William	Low	22,551 (Li)	32.0 (Mb)	50.0 (Mf)	20.0 (Ma)
South Hills	Low	32,285 (Mi)	33.0 (Mb)	63.5 (Hf)	10.5 (La)
Westcliff	Low	47,754 (Hi)	28.2 (Mb)	53.9 (Mf)	15.7 (Ma)
Logan	Low	23,646 (Li)	36.0 (Mb)	48.0 (Lf)	32.0 (Ha)
Ridglea Hills	Medium	47,404 (Hi)	13.0 (Lb)	50.0 (Mf)	2.2 (La)
Carter Park	Medium	23,751 (Li)	31.8 (Mb)	50.6 (Mf)	17.9 (Ma)
Meadowbrook	Medium	31,299 (Mi)	32.3 (Mb)	58.1 (Hf)	15.0 (Ma)
McRae	Medium	24,106 (Li)	35.3 (Hb)	57.6 (Hf)	18.1 (Ma)
DeZavala	Medium	26,917 (Li)	30.4 (Mb)	47.1 (Lf)	13.0 (Ma)
Helbing	Medium	30,576 (Mi)	43.4 (Hb)	43.4 (Lf)	32.7 (Ha)
Kirkpatrick	Medium	28,419 (Li)	17.1 (Lb)	42.9 (Lf)	8.6 (La)
Westcreek	Medium	46,391 (Hi)	31.9 (Mb)	55.7 (Mf)	9.8 (La)
Richard Wilson	High	30,413 (Mi)	27.0 (Mb)	57.1 (Mf)	12.7 (Ma)
Daggett	High	28,363 (Li)	23.6 (Lb)	58.4 (Hf)	12.6 (Ma)
George Clarke	High	31,595 (Mi)	38.6 (Hb)	58.1 (Hf)	15.9 (Ma)
Shulkey	High	48,324 (Hi)	24.0 (Mb)	56.0 (Hf)	6.0 (La)
MEAN		32,072	29.6	54.2	15.7 (Ma)

= Same stratification level in 4 categories

= Same stratification level in 3 categories, with the other two categories at the same level

Table 3. Stratification of Variables of Restaurant Counts, BMI, T2DM Risk, and Acanthosis Nigricans

Income. When income levels are compared to the number of fast food restaurants, three schools fell into the low categories of both variables: Briscoe, Versia William, and Logan. Only one high-income school, Shulkey, corresponded with the high category of fast food restaurants. One low-income school, Daggett, had high numbers of fast food restaurants, and one high-income school, Westcliff, had low numbers of fast food restaurants.

Careful examination of restaurant sites reveals that many are located along highway and major street corridors. The greatest degrees of clustering appear to be at Carter Park, George Clarke, and Helbing, low- and low-medium-income schools; but this apparent clustering may be due more to road traffic patterns than to school proximity (Fig 2).

It cannot be concluded from these data that fast food restaurants in Fort Worth have been deliberately placed near elementary schools, as has been reported in previous research. The economic and convenience factors afforded by proximity to major roadways seem to exert the greater influence in fast food restaurant locations. However, the proximity of the schools cannot be completely discounted as a decision point in the siting of these restaurants, as they do fall within reasonable walking and driving distances of the schools and their residential neighborhoods.

Obesity. Three schools had low percentages of obesity: Ridglea Hills, Kirkpatrick, and Daggett. McRae, George Clarke, and Helbing all fell into the high-obesity category. All of the low-restaurant schools had medium levels of obesity, while there was no clear obesity pattern for medium- and high-restaurant schools. Both the highest and lowest obesity schools were in the medium-restaurant range (Fig. 3).

There does appear to be a pattern of greater restaurant clustering around higher-obesity schools. Helbing, George Clarke, and Carter Park are all fairly high-obesity schools, and fast food restaurants, although perhaps fewer in number, seem to congregate more around these schools. A tentative conclusion is that closer proximity to schools may influence children's weight status.

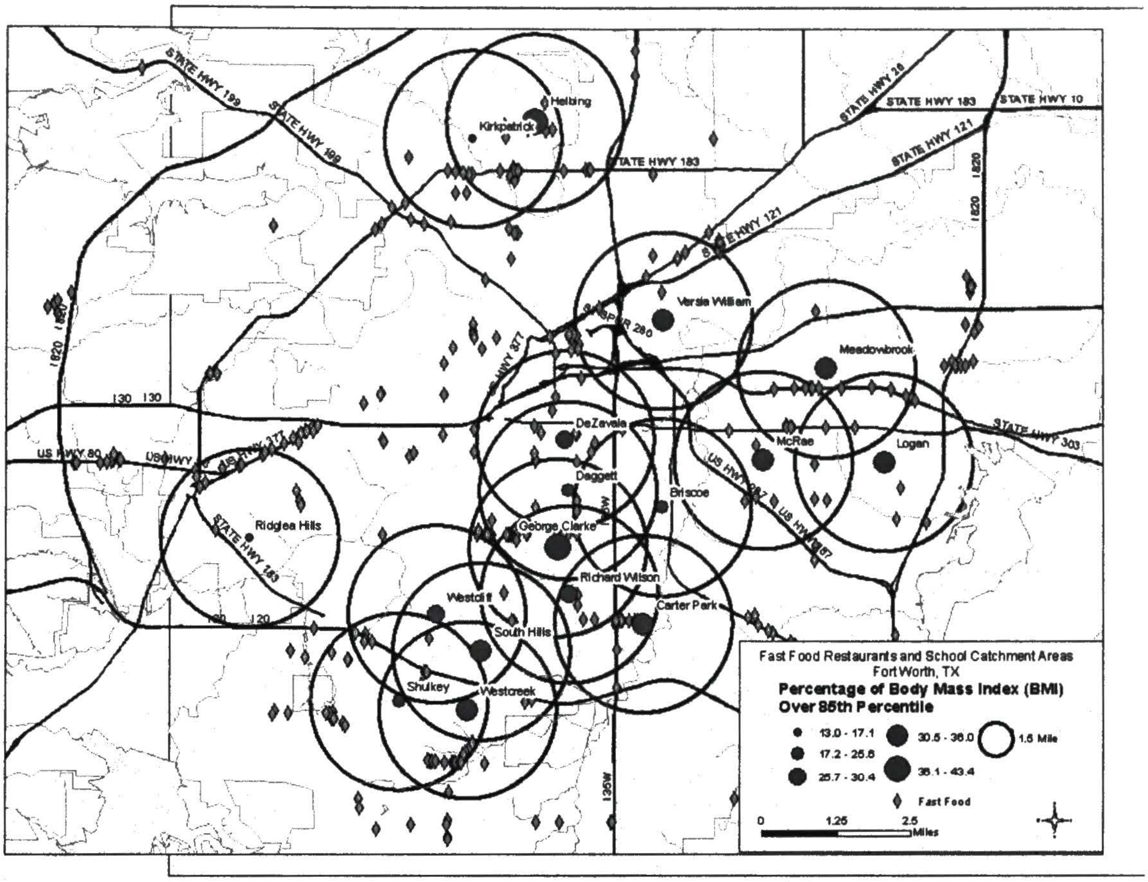

Figure 3. Fast Food Restaurants and BMI in Fort Worth Schools

Family History of DM. Four schools were in the low category of family history of diabetes (FMHDM): Logan, Dezavala, Helbing, and Kirkpatrick. Six schools were high FMHDM: Meadowbrook, South Hills, McRae, Daggett, George Clarke, and Shulkey; two of these, McRae and George Clarke, were also high-obesity, and they were also medium- and high-restaurant schools, respectively. Three of the high-FMHDM schools were also high-restaurant schools. But Logan, which also had low-obesity, was a medium-restaurant school. Daggett and Shulkey, on the other hand, were high-restaurant schools.

Examining the degree of clustering shows no clear pattern, with the exception of George Clarke, which is high-FMHDM, high-obesity, and high-restaurant. But Briscoe and Helbing are medium- and low-FMHDM, and Briscoe has no clustering, while Helbing has moderate clustering.

While there may be a faint spatial pattern of FMHDM to fast food restaurants, it is too indistinguishable to make a definite conclusion. However, there may be a moderate pattern of obesity with FMHDM.

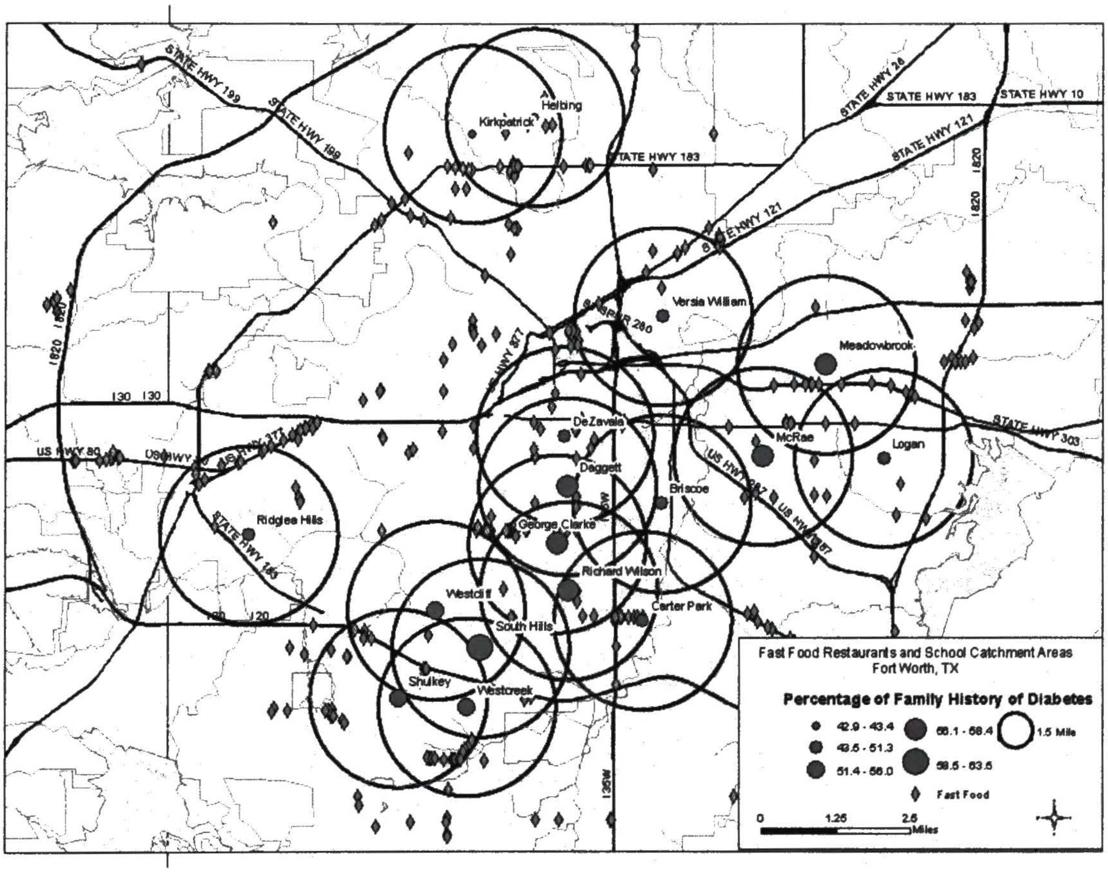

Figure 4. Fast Food Restaurants and Diabetes Risk in Fort Worth Schools

Acanthosis nigricans. Five schools were low-AN: South Hills, Ridglea Hills, Kirkpatrick, Westcreek, and Shulkey. Three schools were high-AN: Briscoe, Logan, and Helbing. There appeared to be no spatial pattern for different levels of AN compared with levels of restaurant numbers: all were mixed in approximately even distribution with each other. No discernable pattern of clustering was evident. Comparing spatial patterns of AN with those of obesity, Helbing was high-obesity and high-AN, and Ridglea Hills was low-obesity and low-AN. None of the schools was at opposite ends of the stratification levels for these categories. Therefore, a moderately strong spatial pattern of obesity with that of AN is observed.

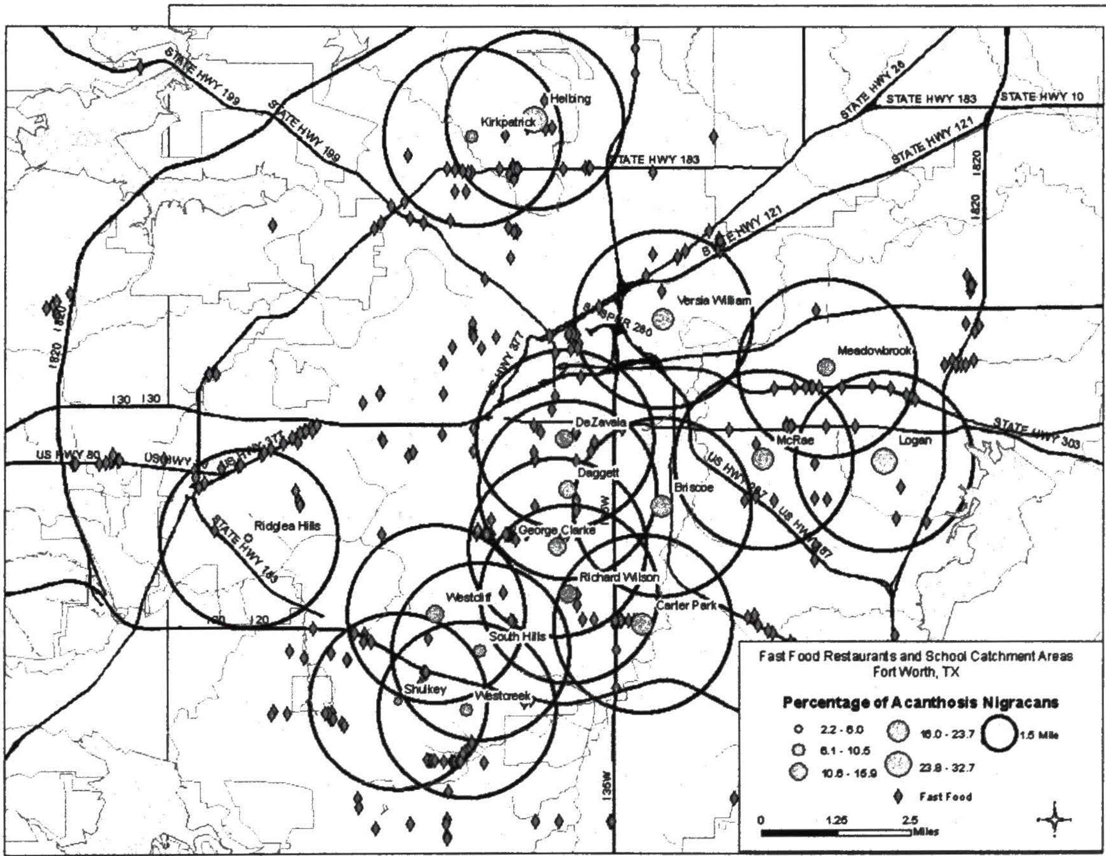

Figure 5. Fast Food Restaurants and Acanthosis Nigricans in Fort Worth Schools

Bivariate Analysis

Correlation and regression analyses were applied to these data to determine if statistically significant associations could be observed. Pearson and Spearman's rho correlations were tabulated, with inconclusive results. There was no correlation between restaurant count and obesity or family history of diabetes. A very weak negative correlation was shown between restaurant count and AN, and a very weak positive correlation was shown between restaurant count and income. That is, the prevalence of AN decreased with increasing numbers of restaurants, and income increased with greater numbers of restaurants. Neither of these correlations was significant at either the 0.01 or 0.05 level (two-tailed).

Linear regression yielded R-squares of 0.002 for BMIP, 0.012 for FAMP, 0.111 for ANP, and 0.096 for income, showing almost no explanatory power for these variables. None of the results was statistically significant. Therefore, we fail to reject the null hypotheses for all variables. There does not appear to be an association between the number of fast food restaurants and the dependent variables of obesity, family history of diabetes, presence of acanthosis nigricans, or income in this population of fifth-grade schoolchildren in Fort Worth, Texas.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

The consumption of fast food has risen at a rapid pace over the past decade and may contribute to the simultaneous increases in the rates of obesity and T2DM in children. Many of the menu items at fast food restaurants are high in calories, protein, and fat, elements that have been shown to contribute to weight gain, and, by extension, to contracting Type 2 diabetes mellitus. Convenient access to sources of fast food would, logically, serve as a route of exposure to these risk factors.

In this study, the number of fast food restaurants within these 17 schools' catchment areas does not seem to be a significant factor in children's obesity status or risk for T2DM. A visual estimate from the geocoded maps generated by ArcMap (Figures 2-5) seems to indicate an average distance of approximately ¾- to 1-mile from schools to the nearest restaurants. There was little evidence of clustering of fast food restaurants around schools. If there is a spatial pattern to the distribution of fast food restaurants in these areas, it appears to be one that is unrelated to school locations. High-traffic roadways, where restaurants would be extremely visible to potential customers, appear to exert the primary influence on the locations of fast food restaurants in Fort Worth.

The fact that these data do not support the hypotheses, however, is not incontrovertible proof that such an association does not exist. Several limitations of this study should be noted, and further measurements are needed, before ruling out this concept.

Mode of transportation. In the Chicago study (Austin et al., 2005 Sep), most of the students walked or rode in cars to and from school; only 6 percent traveled by school bus. Since that study covered all grades in all schools, older students, who are more independent n self-selecting food choices, and who have more freedom in off-campus dining than fifth-graders, were included. Data should be collected on this population's method of transportation to and from school: If most fifth-grade children ride the school bus, there would be no opportunity for them to visit fast food restaurants.

Restaurant site selection. It was observed in this study that many fast food restaurants are located along major roads. The determinants of siting restaurants, such as city ordinances and zoning requirements, land costs, taxes, may exert more influence than a potentially lucrative market. On the other hand, since an average of 22 restaurants are within a 1.5-mile range of the schools, if a primary mode of transportation is by car, many of these restaurants may be on routes between home and school.

Socioeconomic status. Briscoe and Versia William are located on the east side of Fort Worth, historically an impoverished area. Low numbers of restaurants around these schools may reflect companies' reluctance to locate in lower socioeconomic areas. Likewise, there is a slight pattern of medium- and high-restaurant counts in medium- and high-income neighborhoods. Westcliff seems to break this pattern, as it is a high-income area, with low numbers of restaurants. However, Westcliff spans a relatively large geographical area, and is zoned mostly residential; commercial establishments within this neighborhood are few. If Westcliff is removed as an anomaly because of its intrinsic characteristics, the reported trend of locating fast food restaurants in higher-income areas becomes a stronger observation in this study. That would indicate that children in higher-income neighborhoods receive greater exposure to unhealthy effects of fast food than children in lower-income areas, and it would tend to support the hypothesis that fast food contributes to obesity, as medium- and high-obesity schools were found within high-restaurant areas.

Land use classification. The Westcliff illustration above leads to another category of data that is needed: the level and location of commercialization in school neighborhoods. Schools often are surrounded by neighborhoods that are zoned residential; in those cases, an additional buffer would need to be created to account for the impossibility of close proximities. Burdette and Whitaker's study (Burdette & Whitaker, 2004 Jan) found no association between children's obesity and proximity of fast food restaurants to their residences; but this study also did not examine land use classification or nutritional behaviors.

Nutritional behaviors. Although the original study of risk for T2DM in Fort Worth elementary school children did collect data on dietary consumption of fruits, vegetables, and snacks, it did not specifically focus on fast food. In order to assess more accurately fast food as a risk factor, information on fast food menu choices and frequency of fast food ingestion should be collected in this population. In fact, Phase 2 of the DREAMS study is currently collecting these data, and is projected to be available by the end of 2006.

A related issue is the caloric and fat content of fast foods. This study would be strengthened by a closer investigation into the sales volumes of individual fast food restaurants in Fort Worth and the nutritional content of their high-selling menu items.

Migration patterns and time factors. One limitation is that the movement of families into and out of the schools' populations is unknown. Families that had migrated from other school districts or areas may have been exposed to different conditions that influenced dietary habits prior to their moves. Perhaps some children's obesity was acquired in other places. Since the risk factors for T2DM and obesity operate for lengthy periods prior to the onset of these conditions, the exposure levels currently experienced by these populations may not actually be the progenitors of disease. A study design that recorded students' length of residence in the school zone and family immigration patterns over time would ameliorate this difficulty.

Although not found to be statistically significant, there were a few high-restaurant schools that evidenced a higher risk for diabetes due to family history. This may indicate a nominal level of support for the hypothesis that fast foods are a risk factor for diabetes risk.

Recommendations. The theoretical framework for this study was the *human ecology* model, which characterizes health as being constructed of three domains, conceived as a triangle: population, behavior, and environment. "*Population* is concerned with humans as biological organisms, as the potential hosts of disease" (Meade & Earickson, 2000). Population involves such influences as genetics, physiological responses, age, and gender. In this study, the population component was comprised of data on body mass index, acanthosis nigricans diagnosis, and family history of diabetes, gathered from the fifth-grade schoolchildren in 17 schools in the Fort Worth Independent School District. "*Behavior* is the observable aspect of culture. It springs from cultural precepts, economic constraints, social norms, and individual psychology" (Meade & Earickson, 2000). The behavior leg of human ecology considers people's movements from place to place, their exposure and protection to and from risk factors as a result of cultural practices or lifeways, and their creation or modification of environmental conditions. Although behavior was not explicitly addressed in this study, it was inferred through presumptive eating habits. The environment vertex is concerned with natural, social, and built habitats "within which people live, that which directly affects them" (Meade & Earickson, 2000). This study was primarily focused on the "built environment," including fast food restaurants, schools, roadways, and transportation methods and routes.

The three domains of the human ecology of disease model interact to create a picture of the status of health in place and time. Since medical geography is concerned with where and why disease occurs in terms of place and time, human ecology is reasonable theoretical framework in which to pose questions of spatial epidemiology. In this study, children's risk for T2DM and obesity, part of the population component, was hypothesized to stem partially from exposure to unhealthful foods (behavior) provided by seemingly ubiquitous and proliferating fast food restaurants, which formed the habitat sector of the study.

All three of these domains should be examined in more detail before final conclusions can be made. A clinical diagnosis of T2DM in this population would increase the power of any association between exposure and outcome. Similarly, collecting data on the behavior aspect of eating fast foods would verify the supposed exposure. Finally, the nutritional content of menu items offered by the specific fast food restaurants that are located in school neighborhoods would improve the classification of the degree of exposure to unhealthful foods, and would bolster the behavior component for examining this population according to human ecology. For example, if Subway restaurants, which do promote more healthful items, are closer in proximity to some schools than to others, that exposure classification would be less than if Burger Kings were predominant in a school neighborhood.

To place this study and its recommendations in a broader context, it can be considered in terms of the core functions of public health, as outlined in the 1988 Institute of Medicine report, *The Future of Public Health*. The core functions were identified as *assessment*, *policy development*, and *assurance*. The scope and purpose of this study fall within the assessment function, since it was concerned with surveillance, tracking causes, and identifying needs. Although its findings did not tend to support its stated hypotheses, enough evidence is cited herein to warrant further investigation and to make recommendations for policy development and assurance.

In April 2006, U. S. Senator Barack Obama and U. S. Representative Hilda L. Solis co-sponsored The Healthy PLACES Act of 2006, a bill that seeks to create a healthier built environment for children. The proposed legislation would provide grants to states and local communities for research on the relationship between the built environment and health and for programs that address "environmental health hazards"

(American Public Health Association, n.d.). Closer scrutiny of the potential contribution to children's weight and diabetes status would fit well within this program.

The Institute of Medicine, in another report in 2004, challenged the restaurant industry to recognize that some of their food offerings are unhealthful and to limit promotion of these items to children. The report also called on schools to review the nutritional content of food available to students and to increase the proportion of healthful foods.

Heightening public awareness of the obesity and diabetes epidemics in children and of the behavioral and environmental links contributing to this decline in children's health may spur additional legislative and policy efforts to confront the restaurant industry with demands for safer and healthier foods.

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