

2007

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Stephen Borders, Gustavo Rotondaro, Ryan Bosscher

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RESEARCH AND PRACTICE ARTICLE

**Using GIS in Conjunction with Binary Logistic Regression:
Mapping the Adequacy of Prenatal Care Access in Grand Rapids, Michigan**

Stephen Borders, PhD, MSHP¹

Gustavo Rotondaro, MUPDD²

Ryan Bosscher, MPA²

School of Nonprofit and Public Administration¹

Johnson Center for Philanthropy – Community Research Institute²

Grand Valley State University

ABSTRACT:

Background: Early prenatal care is often a prerequisite to a healthy baby. The relationship between adequate prenatal care and improved birthing outcomes is well known. Yet access to adequate prenatal care is complicated by a number of socioeconomic factors related to the mother. These factors include education, ethnicity, insurance type, and the age of the mother. When examining a number of these access measures related to prenatal care access and birthing outcomes, Michigan ranks poorly when compared to other states. In Grand Rapids, Michigan, some of these problems are particularly acute. Grand Rapids exceeds the statewide rates in infant mortality, teen pregnancy and mothers receiving less than adequate prenatal care.

Objective: Apply GIS to analyze the spatial aspects of inadequate prenatal care access and assist public health officials in identifying census block groups among the 32 Grand Rapids neighborhoods where risk factors are the greatest.

Methods: Using vital statistics data on 22,004 live births recorded in Grand Rapids between 1998 and 2003, a logistic regression model was employed to determine the significance of various independent variables associated with inadequate prenatal care access as measured by the Kessner Index.

Results: A number of variables (maternal smoking, maternal alcohol use, Medicaid as primary insurance type, ethnicity, and education of the mother) were found to be associated with inadequate prenatal care access. A number of maps were then prepared to examine the spatial distribution and relative severity of each variable within the city, uncovering a number of proximal relationships.

Conclusions: These maps are being used to identify problem areas and to tailor intervention programs to improve prenatal care access in Grand Rapids.



INTRODUCTION:

Access to health care services is an extremely broad concept and encompasses a variety of issues. Access to health care services also reflects one of the two overarching Healthy People 2010 goals and is intertwined within a number of key policy questions (U.S. Department of Health and Human Services, 2000). Simply having health insurance coverage, however, does not guarantee access to services. There are a number of factors that impede access to care. Provider access is frequently cited as a barrier to care, especially among those living in rural areas and those covered by state Medicaid programs (Berman, Dolins, Tang, & Yudkowsky, 2002; Greene, Blustein, & Weitzman, 2006; Ricketts, 1999; Watson, 1995). Health insurance coverage can only lead to actual utilization if there is sufficient provider capacity to meet demand. Without adequate provider availability, access to requisite health care services is impeded even if a means to pay for the delivery of services exists (Aday & Andersen, 1981).

While physician capacity factors play an important role in health care access, there are also a number of financial and other factors associated with access and utilization of health care services (Andersen & Aday, 1978; Andersen & Newman, 1973). Anderson and Newman developed a model identifying factors associated with access to health care, calling these the individual determinants of health care utilization. These factors can be summarized into three types of factors: predisposition factors, enabling factors, and illness factors. Predisposition factors consist of such aspects as age, marital status, and race or ethnicity. Enabling factors consist of such aspects as health insurance type, place of residence and income. Illness factors consist of such aspects as disability, diagnosis and symptoms. Some of these factors are associated with improving access to the health care system while others present barriers to the health care system.

In addition to recording the birth event, vital statistics from birth certificate data have become an important source of information in measuring not only prenatal care access, but also many of the individual determinants of health care access and outcomes. As a result, the data captured from the birth certificate can help policy makers in evaluating the quality of care being delivered to pregnant women in the United States (Roohan et al., 2003). Birth certificate data are used to assess birth outcomes, such as infant birth weight, infant mortality, maternal tobacco use, and infant birth weight (Din-Dzietham & Hertz-Picciotto, 1998; Murphy, Butler, Peterson, Heart, & Murphy, 1996; Schulte et al., 1996). The data are extremely helpful to policymakers because all 50 states are required to collect these data for all live births using a common definition adopted by the World Health Organization (David, 1980).

When examining a number of these access measures related to prenatal care access and birthing outcomes, Michigan ranks poorly when compared to other states. The 2002 national infant mortality rate was 7.0 per 1,000 births (Kochanek & Smith, 2004) as compared to 8.2 per 1,000 births in Michigan (The Annie E. Casey Foundation, 2006a). When examining infant mortality among children born to African-American women, twice as many African-American babies as White babies die ("NIH finds Michigan project to improve racial disparities in pregnancy outcomes", 2004). The percent of Michigan mothers having low birthweight babies (8.2%) (The Annie E. Casey Foundation, 2006a) also exceeds the national



average of 7.9% (The Annie E. Casey Foundation, 2006b). In Kent County, Michigan, some of these problems are particularly acute. Kent County exceeds the statewide rates in infant mortality, teen pregnancy and mothers receiving less than adequate prenatal care (The Annie E. Casey Foundation, 2006a).

Early prenatal care is often a prerequisite to a healthy baby. The relationship between adequate prenatal care and improved birthing outcomes is well known (Carney, Berry, Thompson, & Brozicevic, 1996; Riechman & Florio, 1996). The concept of prenatal care began in the early 1900s and has been credited with reducing infant death. Because increasing access to prenatal care can improve birthing outcomes, this study examined adequacy of prenatal care among mothers in Grand Rapids, Michigan, for the period 1998-2003. A logistic regression model was used to examine the data for the city to predict factors associated with poor prenatal care access as measured by the Kessner Index. The Kessner Index incorporates information from three items recorded on birth certificates: 1) the length of gestation; 2) timing of the first prenatal care visit; and 3) total number of prenatal visits. The index classifies mothers into one of three categories: adequate, intermediate and inadequate. These categories are defined in Table 1. (Kessner, Singer, Kalk, & Schlesinger, 1973).



Table 1: Kessner Index – Criteria for Adequacy of Prenatal Care

Adequacy of Prenatal Care	Gestation (Weeks) ⁴		Number of Prenatal Care Visits
Adequate ¹	13 or less	and	1 or more, or not stated
	14-17	and	2 or more
	18-21	and	3 or more
	22-25	and	4 or more
	26-29	and	5 or more
	30-31	and	6 or more
	32-33	and	7 or more
	34-35	and	8 or more
	36 or more	and	9 or more
Inadequate ²	14-21 ³	and	0 or not stated
	22-29	and	1 or less or not stated
	30-31	and	2 or less or not stated
	32-33	and	3 or less or not stated
	34 or more	and	4 or less or not stated
Intermediate	All combinations other than specified above		

¹ In addition to the specified number of visits indicated for adequate care, the interval to the first prenatal visit has to be 13 weeks or less (first trimester).

² In addition to the specified number of visits indicated for inadequate care, all women who started their prenatal care during the third trimester (28 weeks or later) are considered inadequate.

³ For this gestation group, care is considered inadequate if the time of the first visit is not stated.

⁴ When month and year are specified but day is missing, input 15 for day.

Source: Reprinted with permission from *Infant Death: An Analysis by Maternal Risk and Health Care* (Table 2-3, p 59). Copyright © 1973, National Academy of Sciences. Courtesy of the National Academy Press, Washington, DC.

Although this index measures quantity of care better than either the number or timing of prenatal visits alone, it does not measure quality of care. A pregnant woman could have made several prenatal visits, but have received substandard care. The index also does not consider the relative risk of the mother. A mother could have been at high risk and have received an intermediate amount of care as measured by the index. However, the quantity of her care may have been inadequate given her condition. Moreover, in many cases the index relies upon accurate recall of onset of care and number of visits. Despite these shortcomings, the Kessner Index remains a good comparative measure of prenatal care adequacy (Forrest & Singh, 1987; Liberatos & Kiely, 1991).

While numerous studies have established the link between prenatal care access and socioeconomic factors that impede access to care, few have examined these aspects spatially. As a result, our research had two primary goals. First, we sought to determine which socioeconomic variables were associated with inadequate prenatal care access in Grand Rapids. Second, upon



assessing the correlates of poor prenatal care access, we identified neighborhoods in Grand Rapids using geographic information systems (GIS) where access problems were most acute. In addition, we also used GIS to map the socioeconomic variables associated with inadequate prenatal care.

METHODS:

This study examined birth certificate data provided by the Kent County Health Department in Grand Rapids, Michigan. The data set included all live births recorded in the county between 1998 and 2003. During that time, 22,004 live births were recorded among mothers living within the city. In addition to recording the birth event, the data set also included basic demographic information, pregnancy history, prenatal care, birthweight and source of payment. Pregnancy risk factors were also included in the data set, such as alcohol and tobacco use during pregnancy.

Logistic Regression Analysis

One research goal was to answer questions about how socioeconomic factors are associated with access and utilization of prenatal care services in Grand Rapids. Multivariate analysis can assist in understanding how the convergence of these factors work together and identify the barriers that contribute the most to the problem of prenatal care access. It, therefore, is important to explore how the various socioeconomic characteristics jointly affect access to prenatal care. To analyze these impacts, we used a logistic regression model. All statistical analyses were performed using SPSS version 13.0.1 for Windows. We used a logistic regression model to test our hypothesized relationships between mothers receiving inadequate prenatal care and the various socioeconomic variables described earlier. While this approach is helpful in determining the odds or risks that individuals with certain socioeconomic characteristics face in being an inadequate user of prenatal care, it does not completely describe or account for all of the factors associated with the problem of poor access to prenatal care.

Geographic Information Systems Analysis

The GIS analysis and maps were created using ArcGIS version 9.2. Using GIS software and a process called “geocoding” or “address matching,” birth records were assigned geographic coordinates (X,Y) to create point locations using the mother’s residence address from the birth certificate records. This process yielded an average of 94.7% of addresses matched between 1998 and 2003. Records that could not be geocoded or address matched were excluded from the GIS portion of the analysis. Minimum standards for match rates are applied based on the accuracy needed in a study. In many cases, an 85% match rate is considered to be an acceptable standard (Ratcliffe, 2004). However, it is important to note that a higher match rate results in lower potential for error in spatial patterns.

In addition to creating point locations of birth events, special consideration was given to preserve the privacy of individuals. The agreement with the Kent County Health Department and the Johnson Center for Philanthropy at Grand Valley State University requires compliance to minimum statistical safeguards when presenting data. These guidelines are based on specific population thresholds and number of protected health information (PHI) related events found in a



given geography. When these standards cannot be met due to the limited number of PHI related events in a given geography, all PHI related events for these geographic areas must be expressed only as occurrences per 1,000. Each birth record and corresponding maternal and infant information was assigned and aggregated to the 2000 Census block groups. The U.S. Census Bureau defines a block group as a geographic subdivision of a census tract with a population average ranging between 1,500 – 3,000 people (U.S. Census Bureau, 2004). Thematic mapping was used to represent how inadequate prenatal care and the variables associated with inadequate prenatal care were spatially distributed at the block group level.

RESULTS:

A number of earlier studies have linked prenatal care access and outcomes. The predictor variables included in this model were chosen due to the associations found in previous studies as well as data availability (Adams, Gavin, & Benedict, 2005; Carney, Berry, Thompson, & Brozicevic, 1996; Healy et al., 2006; Laditka, Laditka, Mastanduno, Lauria, & Foster, 2005). A logistic regression was employed to understand what factors most influence prenatal care access or the lack thereof. The results of the multivariate analysis are shown in Table 2.

Table 2: Independent variables obtained from birth certificate records on mothers living within Grand Rapids, Michigan (1998-2003)

Variable	DF	Probability (P<.05)	Odds Ratio
Maternal Smoking (1 = yes, 0 = no)	1	.01	1.440
Alcohol (1 = yes, 0 = no)	1	.01	2.264
Age of mother > 34 (1 = yes, 0 = no)	1	.22	1.121
Age of mother < 17 (1 = yes, 0 = no)	1	.01	1.600
Payment (1 = Medicaid, 0 = Private insurance)	1	.01	1.910
Race of Mother (1 = African- American, 0 = Other)	1	.01	1.544
Education of Mother (1 = Less than high school degree, 0 = high school degree or greater)	1	.01	1.428



Nearly all of the variables were significant in the logistic regression when examining the correlates of inadequate access to prenatal care. Maternal smoking, maternal alcohol use, age of the mother < 17 years old, payment type (Medicaid), ethnicity of the mother (African-American), and education (less than a high school degree) of the mother were all significant ($p < .01$). The relationship between alcohol consumption during pregnancy and inadequate access to prenatal care was particularly strong ($[OR] = 2.264, p < .01$). From the logistic regression, we can also develop probabilities and determine how each of the significant factors either increase or decrease the overall probability. The overall odds of a mother reporting inadequate prenatal care in Grand Rapids during the period of interest was about 8%.

To determine the relative magnitude of each of the independent variables, we computed the probability of a woman reporting inadequate access to prenatal care during the study period. We calculated the predicted probability of a woman reporting inadequate access to prenatal care if she had one of the characteristics that was significant in the logistic regression. Examining the independent variables one at a time permitted us to determine the extent to which the probability of reporting inadequate access to prenatal care is changed in response to changes in a woman's socioeconomic characteristics. Most notably, alcohol consumption during pregnancy had the largest impact, increasing the probability of a woman reporting inadequate access to prenatal care to 15.3%. This was followed by insurance type, with the probability of a woman reporting inadequate access to prenatal care increasing to 13.3% if Medicaid was the primary source of payment for the delivery. Being African-American or being under the age of 17 increases the probability of a woman reporting inadequate access to prenatal care 11% and 11.3% respectively. In addition, the probability increased to 10.3% if she reported smoking during pregnancy and to 10.3% if she had less than a high school education.

Once the "geocoding" or "address matching" process was complete and birth records assigned to census block groups, the final data set was summarized and joined to the GIS layer containing the 2000 Census block group polygons. We created rates of inadequate prenatal care and other associated variables for each block group based on total number of births in each block group.

The next step was to decide the type of thematic mapping and classification method to use. Choropleth maps are the most common type of thematic mapping used for exploratory analysis. A choropleth map uses ranges of values and colors to distinctively represent a particular event in a given area. Understanding the extent, arrangement (patterns), and variation of both spatial outliers and intensity in values associated with census block group polygons can help identify areas where the problem of inadequate prenatal care and variables associated with it are most acute. We used the standard deviation to classify and organize spatial outliers in the data. Individual block groups were color coded with lighter (around the mean) or darker (less or exceeding the mean) shadings.

Preliminary results suggest similar spatial patterns between the level of inadequate prenatal care, education, Medicaid as the payment source of the birth, and ethnicity (African-American) of the mother in the census block groups. Block groups in central city neighborhoods consistently experienced high rates of inadequate prenatal care, low educational levels, Medicaid as the



payment source of the birth, and high concentration of African-American mothers. For instance, some block groups in central city neighborhoods recorded up to 84.1% of its population over 25 years of age without a high school diploma as compared to 22% in Grand Rapids and 16.6% in Michigan in 2000 (U.S. Census Bureau, 2001). Similarly, block groups in non-central neighborhoods consistently experience high rates of intermediate and adequate prenatal care and educational levels.

A less apparent spatial pattern was found for mothers consuming alcohol or smoking during pregnancy. In these cases, census block groups experiencing high rates of alcohol and smoking consumption during pregnancy were isolated and differ from the pattern found in previous variables associated with inadequate prenatal care.



Figure 1: Adequacy of Prenatal Care in Grand Rapids, MI. Areas exceeding the mean value for this variable are shaded with darker patterns.

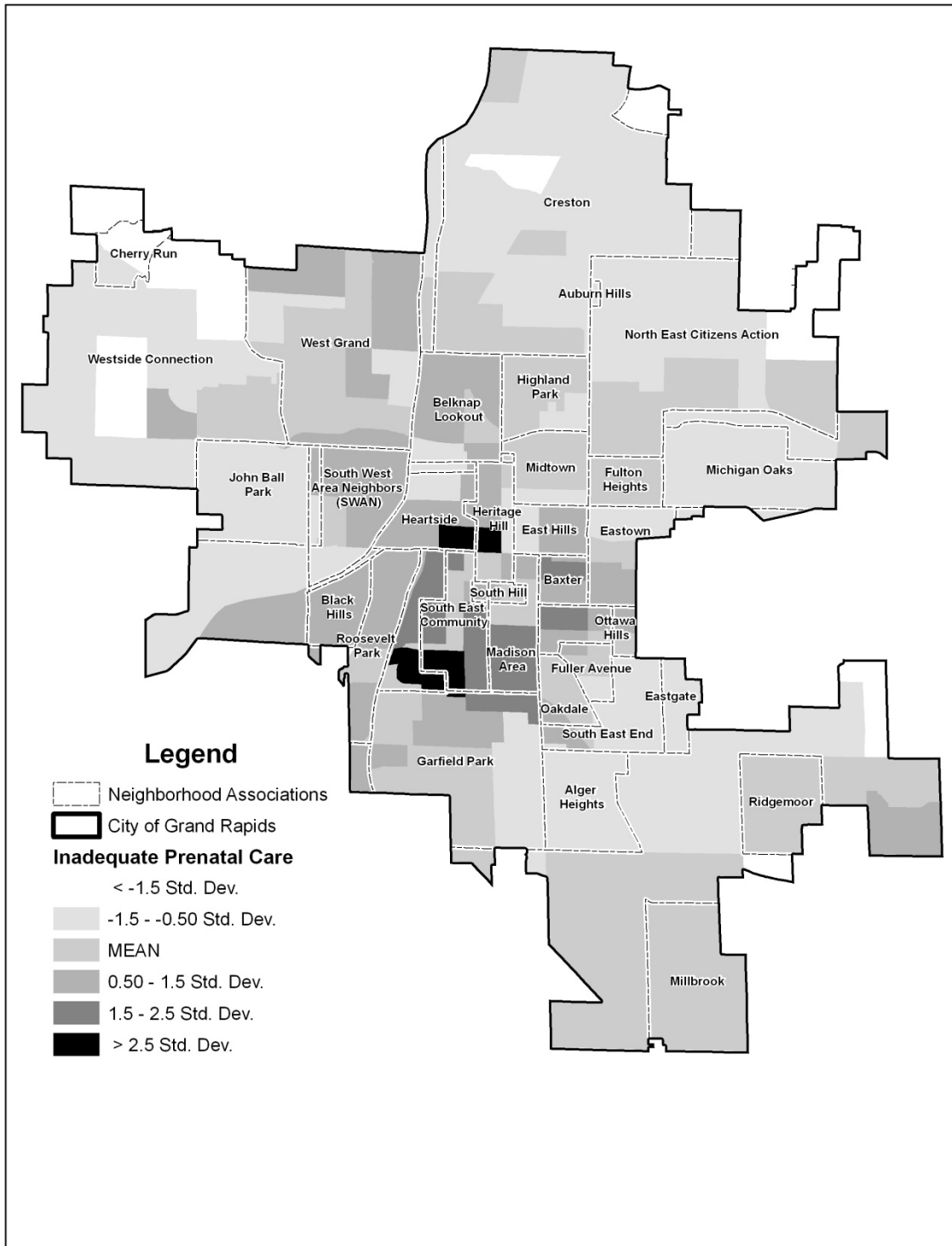


Figure 2: Mothers with less than a high school degree in Grand Rapids, MI. Areas exceeding the mean value for this variable are shaded with darker patterns

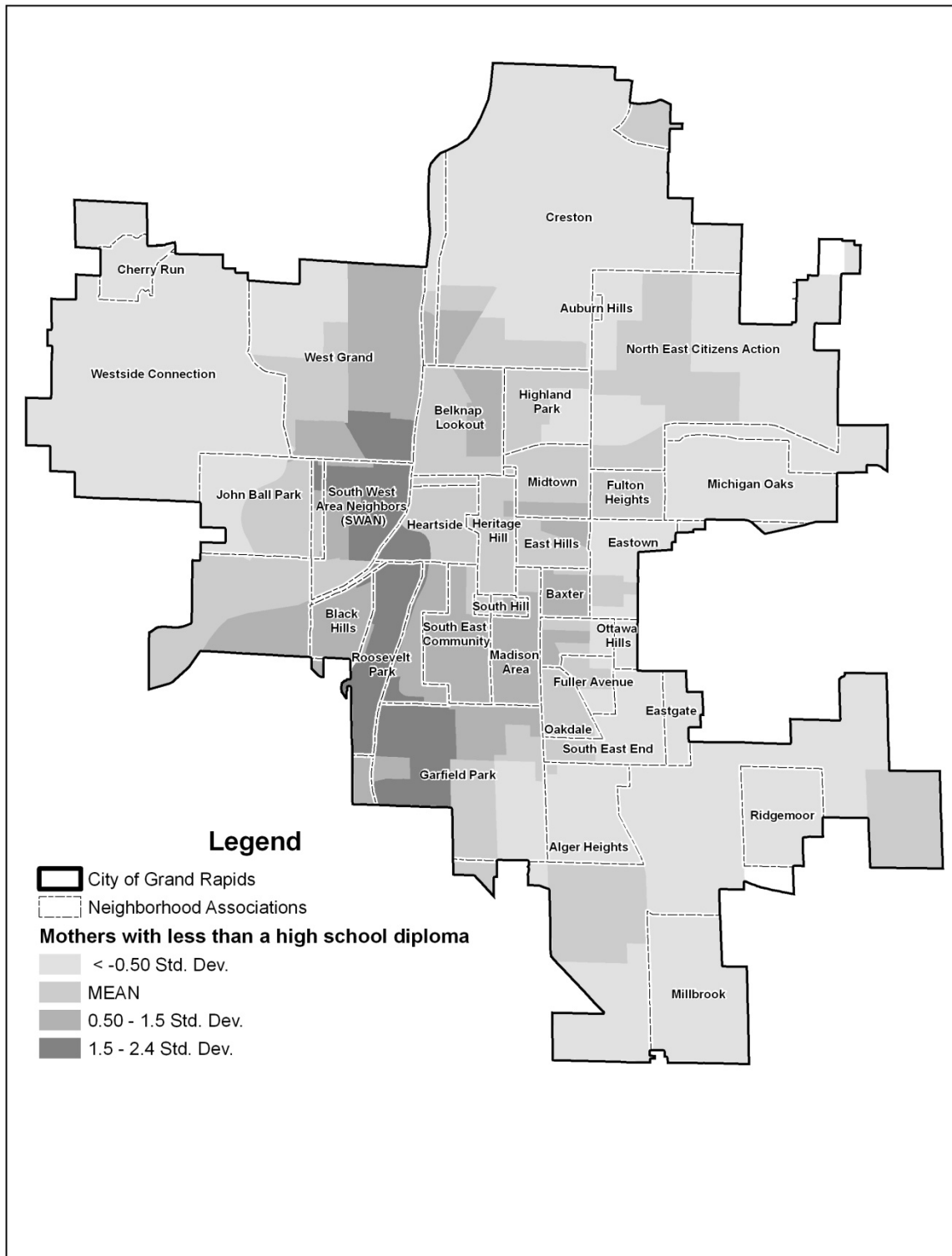


Figure 3: Mothers that whose primary ethnicity is African-American in Grand Rapids, MI. Areas exceeding the mean value for this variable are shaded with darker patterns.

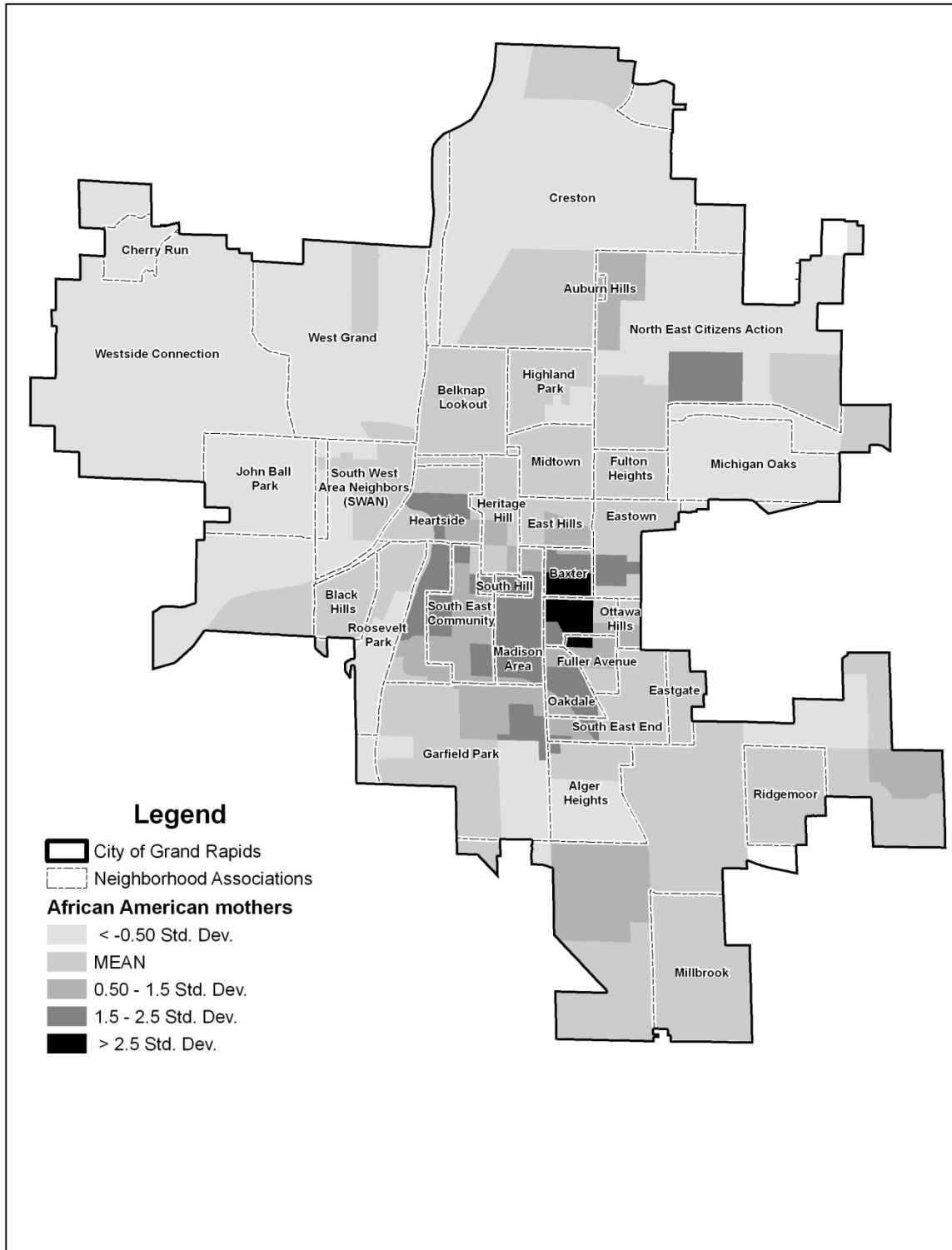


Figure 4: Mothers that smoked during pregnancy in Grand Rapids, MI. Areas exceeding the mean value for this variable are shaded with darker patterns.

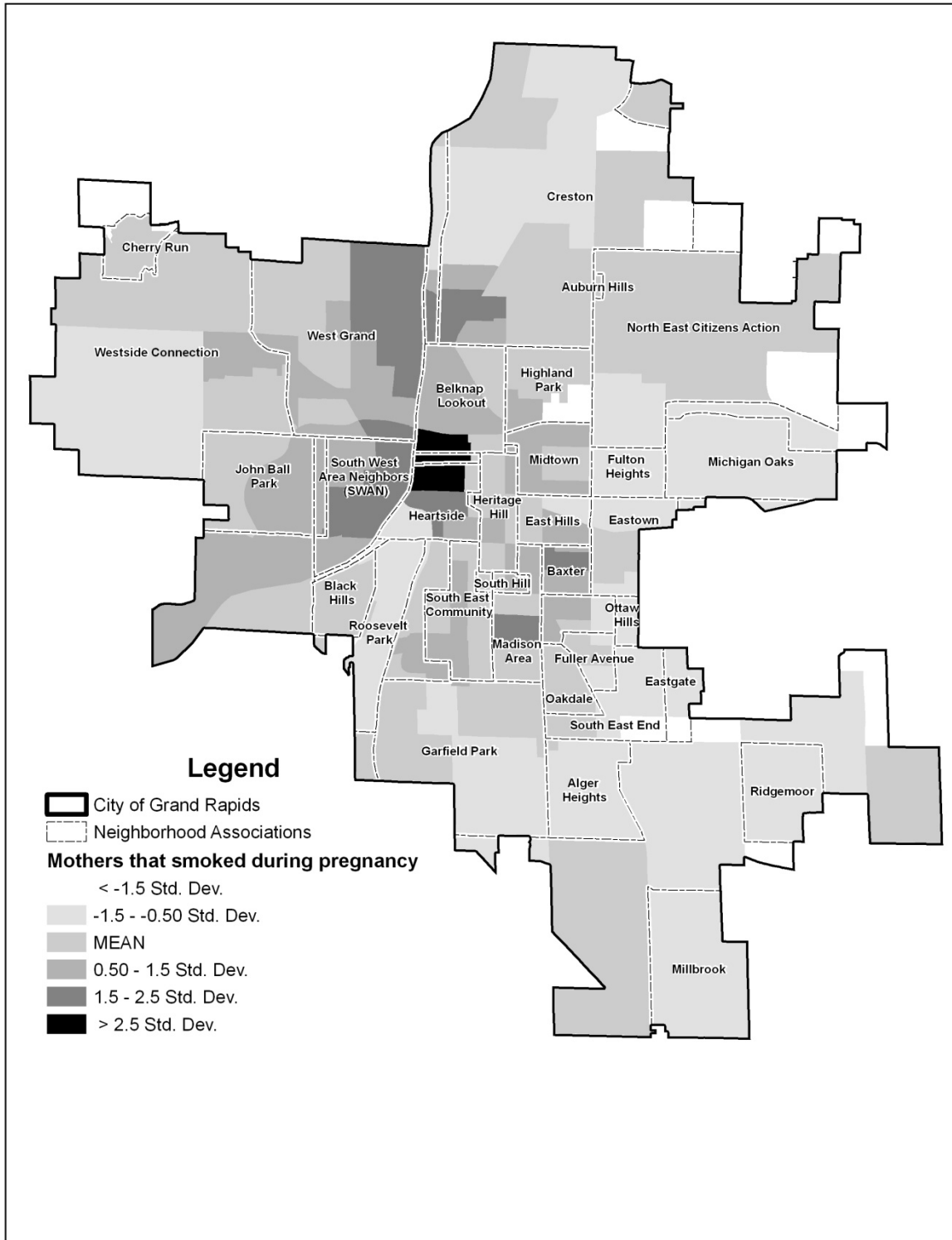


Figure 5: Mothers that consumed alcohol during pregnancy in Grand Rapids, MI. Areas exceeding the mean value for this variable are shaded with darker patterns.

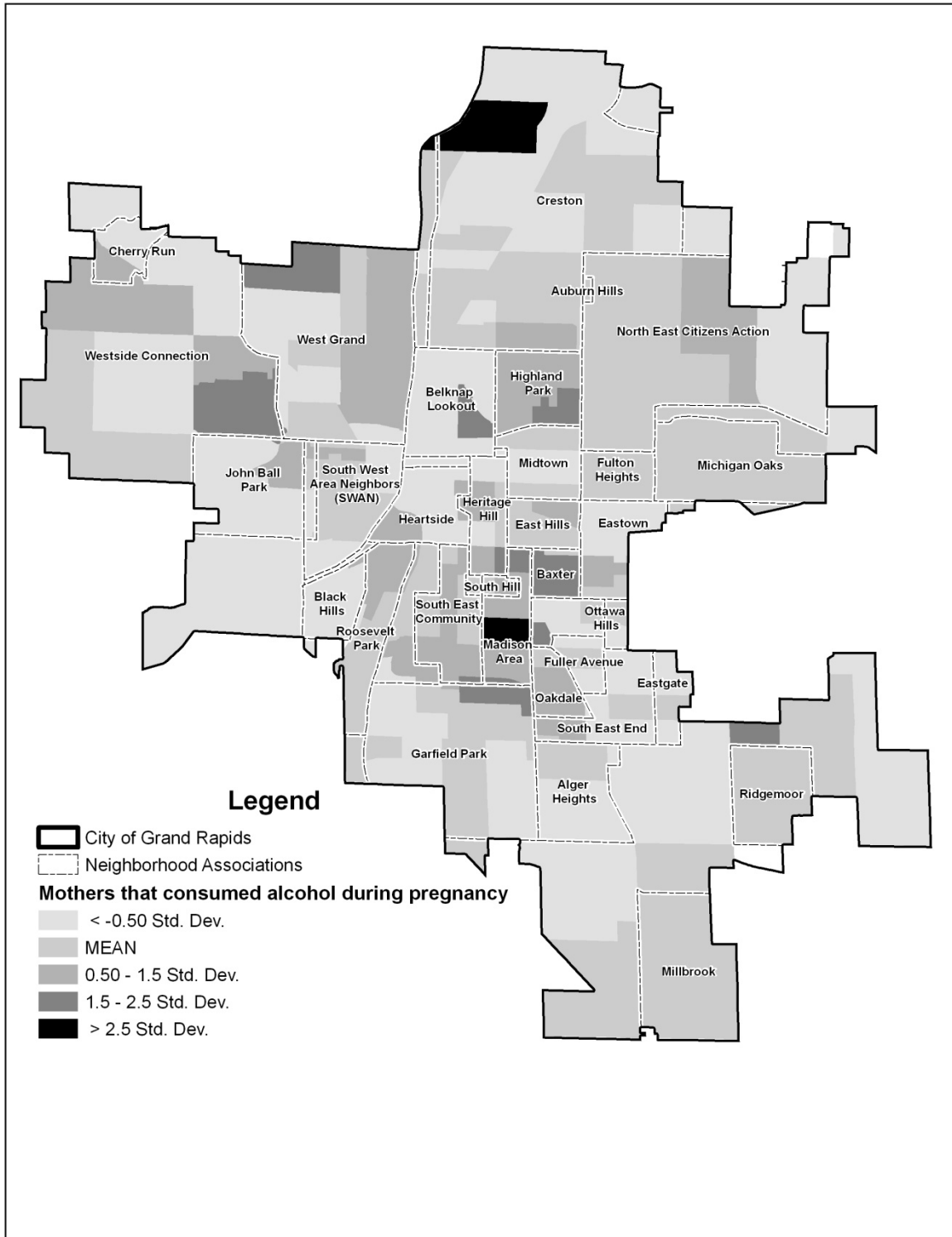
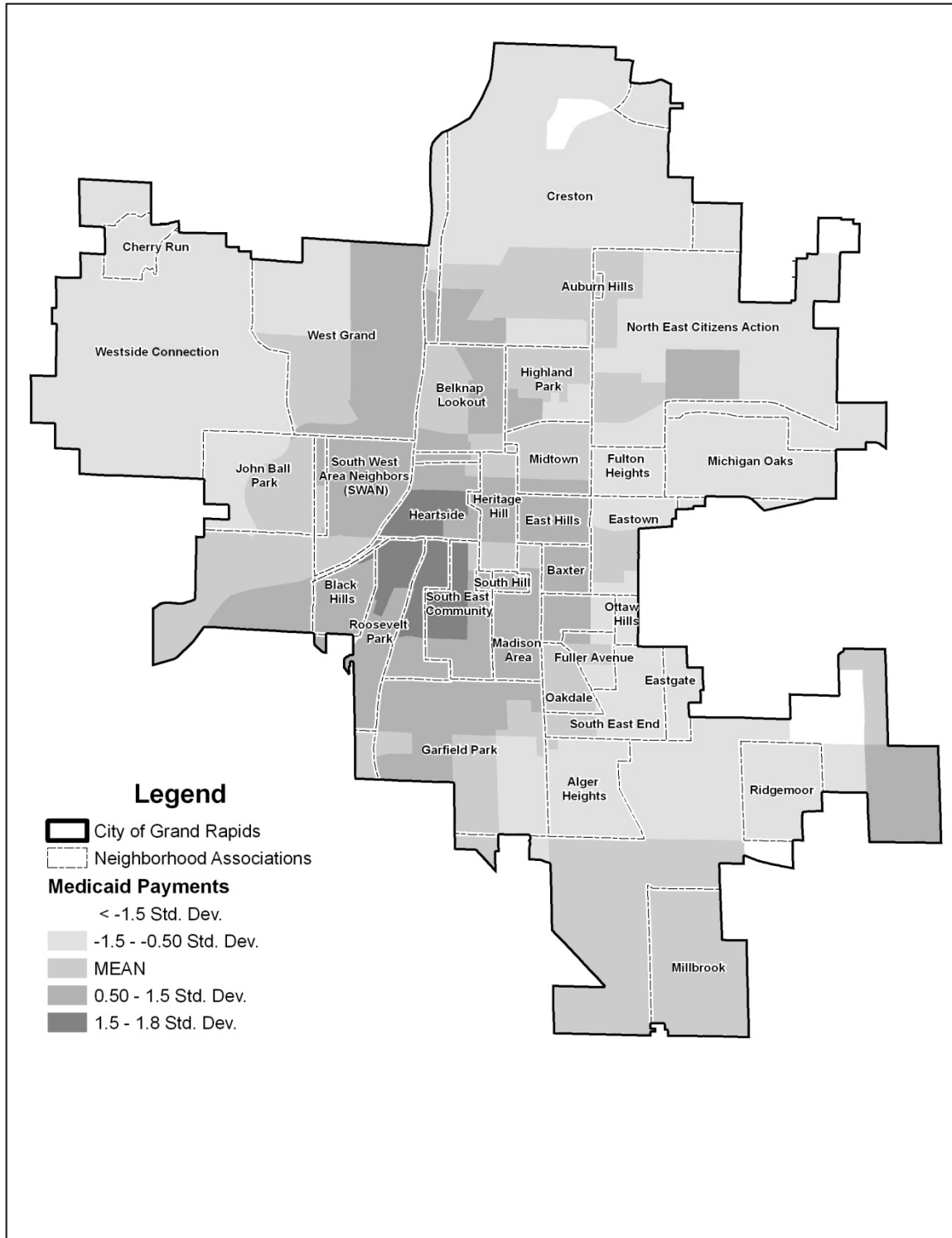


Figure 6: Medicaid payments in Grand Rapids, MI. Areas exceeding the mean value for this variable are shaded with darker patterns.



DISCUSSION:

Other studies, including those that involved similar types of analyses, have documented various socioeconomic barriers and factors associated with poor access to prenatal care (Adams, Gavin, & Benedict, 2005; Carney, Berry, Thompson, & Brozicevic, 1996; Healy et al., 2006; Laditka, Laditka, Mastanduno, Lauria, & Foster, 2005). However, these studies did not focus on the spatial aspects of inadequate access to prenatal care. Although our data did not permit the analysis of birthing outcomes, the regression analysis demonstrated that several socioeconomic characteristics were associated with poor prenatal care access. These findings, coupled with the spatial analysis, provide potentially important geographic areas and socioeconomic factors for policy interventions.

In examining access to prenatal care or lack thereof in Grand Rapids, the occurrence is clearly not a random event. A number of well defined areas reporting inadequate access to prenatal care dominate certain sections of the city, while other well defined areas exhibit adequate/intermediate access to prenatal care. By understanding the factors related to the census block groups of the city exhibiting barriers to prenatal care, public health officials can develop appropriate intervention programs to target those areas most in need. For example, programs such as the Maternity Outpatient Medicaid Services, also known as the MOMS program in Michigan, which provides maternal support services to high risk expectant mothers, can use the results of this project to tailor outreach programs to target areas and clients with risk factors associated with inadequate prenatal care. The Strong Beginnings program offered through Spectrum Health could perhaps benefit most from this research because of the singular focus of the program on reducing disparities in pregnancy outcomes and prenatal care access among African-Americans in Grand Rapids. Expectant mothers exhibiting one or more of the following risk factors related to poor prenatal care access could be targeted immediately for increased outreach efforts: African-American, less than a high school degree, on Medicaid, under the age of 17, consume alcohol, and/or smoke. The results from the mapping can provide clues about exactly where to invest such efforts so that limited resources can have the greatest impact. Despite knowing little about the outcomes of the mothers who received inadequate prenatal care from this research, the association between adequate prenatal care and improved birthing outcomes is strong and the push to eliminate health disparities must continue.

The validity of vital records data taken from birth certificates has been called into question by a number of researchers. Many of the data elements used in this study rely on accurate recall of the mother at the time of birth. Researchers comparing birth certificate data to actual medical records have found good to fair reporting on a number of data elements, including prenatal care, obstetrical procedures and labor and delivery events (Buescher, Taylor, Davis & Bowling, 1993). Researchers in Georgia specifically examined the amount, timing, and adequacy of prenatal care and found that birth certificate data were inaccurate in indicating the actual level of prenatal care received due to the fact that many women actually overestimated the care they received (Clark, Chun-Mei & Burnnet, 1997). Thus, the results and maps here should be interpreted cautiously and most likely under represent the true magnitude of the proportion of women receiving inadequate prenatal care in Grand Rapids.



While this research identifies a number of factors related to inadequate prenatal care access, clearly the factors identified here do not fully explain all of the variability associated with inadequate prenatal care access. For example, the spatial relationships between African-American mothers and inadequate prenatal care are quite similar. That is, where African-American mothers are most concentrated in Grand Rapids, so are the areas exhibiting the highest levels of mothers receiving inadequate prenatal care. In addition, there are also a number of spatial relationships between education, Medicaid as the payment source for the birth, and inadequate prenatal care. Although the spatial relationships between mothers that smoked during pregnancy and mothers that drank during pregnancy were significant predictors of inadequate prenatal care utilization, the spatial relationships are much less striking. For example, the map of mothers who smoked during pregnancy reveals a number of different spatial patterns than those who received inadequate prenatal care. Thus, clearly more research is needed to fully understand why such inequities in prenatal care access exist and what can be done to eliminate those discrepancies.

Furthermore, we can say little about the current health care service delivery network in Grand Rapids, especially in terms of the spatial relationships to expectant mothers or its efficacy. We recommend a greater focus on more localized conditions at the neighborhood or census block level, especially in areas exhibiting poor prenatal care access. Such an approach would provide greater insights to the problems expectant mothers are facing in receiving prenatal care. In addition, future research should include a systematic examination of the prenatal health care delivery system in Grand Rapids to identify if and where service gaps may occur. The delivery of health care services is only part of the access equation. We recommend further research in regard to surveying expectant or recent mothers in areas plagued by prenatal care access problems. A deeper probing of barriers that can impede access to prenatal care is warranted. For example, future research should most likely focus on barriers such as transportation, work, daycare, cultural, educational and language barriers. Better data on resources and barriers would provide opportunities to more accurately map and measure gaps in health service delivery, transportation, and daycare. Only by fully understanding the access problem can appropriate interventions be developed.

The focus of this research was born out of the markedly poorer pregnancy outcomes and access problems among African-Americans in Grand Rapids. While the data indicate numerous disparities in access and outcomes among African-Americans in Grand Rapids, there are a number of other demographic characteristics worthy of examination in future studies. We also suggest future studies examining birthing outcomes and access to prenatal care focus on the growing Latino population in Grand Rapids. Many of the expectant Latino mothers share many of the same demographic characteristics associated with inadequate prenatal care access, especially in regards to educational status and Medicaid as the primary payer of health care services. Although African-Americans and Latinos share some of these same demographic characteristics, the prenatal care access issues may be different and thus result in different strategies in targeting Latino mothers.



Acknowledgments

We thank Jim Smedes of the Kent County Health Department for supplying the data and technical assistance.

Human Participant Protection

The study protocol was approved by the institutional review board of Grand Valley State University.

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