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Individual- and Neighborhood-Level Determinants of Emergency Department Utilization Among Patients with Diabetes in South Carolina

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INDIVIDUAL- AND NEIGHBORHOOD-LEVEL DETERMINANTS OF EMERGENCY DEPARTMENT UTILIZATION AMONG PATIENTS WITH DIABETES IN SOUTH CAROLINA

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ABSTRACT

AIM: The primary aim of this study was to evaluate the geographic variation in emergency department (ED) use in South Carolina using geographical information systems (GIS) and to examine the effects of both individual- and neighborhood-level characteristics on frequent ED use among patients with diabetes.

METHODS: ED discharge data for 2013 was geocoded based on patients' residential ZIP code using GIS. Frequent ED use among patients with diabetes was defined as three or more ED visits between January 1, 2013 and December 31, 2013. The boundaries for each neighborhood were defined by the U.S. Census Bureau ZIP Code Tabulation Areas (ZCTAs) and the demographic and socioeconomic characteristics describing each ZCTA were obtained from the 2013 American Community Survey. Population standardized density of ED patients with diabetes as well as the average number of ED visits per patient with diabetes were calculated for each ZCTA and analyzed for spatial patterns and non-spatial correlations with neighborhood-level determinants. The relationships between individual- and neighborhood-level variables with frequent ED use were assessed using random-intercept multilevel modeling.

RESULTS: A total of 350 out of 423 ZCTAs were included in this analysis, with a sample size of 91,461 ED patients with diabetes who accumulated over 166,905 ED visits in South Carolina during 2013. The standardized density of ED patients with diabetes as well as the average number of ED visits per patient with diabetes demonstrated spatial clustering to certain geographic locations within South Carolina. Indicators of low neighborhood socioeconomic status and family structure were significantly correlated with a higher density of patients with diabetes and an elevated number of ED visits per patient with diabetes. In multilevel analyses, patients with diabetes who were younger, African American females, or Medicaid/Medicaid beneficiaries were more likely to be frequent ED users. At the neighborhood-level, measures of material deprivation and rural/urban status of a neighborhood demonstrated little to no effect on the propensity toward using the ED in this population.

CONCLUSION: Exposure to certain neighborhood-level characteristics may increase or decrease an individual's dependence upon the ED for routine care. However, after accounting for individual-level characteristics via multilevel modeling, neighborhood-level measures of material deprivation and rural/urban status did not account for much of the unexplained neighborhood heterogeneity. Whereas, individual-level measures of age, sex, race, and primary source of payment remained significant predictors of frequent ED use. The spatial clustering of ED patients with diabetes and elevated ED visits per patient with diabetes to certain geographic locations in South Carolina indicates that future research should spatially explore this relationship in order to understand the behavior process leading to ED utilization in this high risk population.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACS .... American Community Survey

ACSC .... Ambulatory Care Sensitive Condition

AIC .... Akaike's Information Criterion

BIC .... Bayesian Information Criterion

ED .... Emergency Department

GIS .... Geographic Information Systems

ICD .... International Classification of Diseases

IOR .... Interval Odds Ratio

MOR .... Median Odds Ratio

NAD .... North American Datum

PO .... Post Office

RFA .... Revenue and Fiscal Affairs

RUCA .... Rural-Urban Commuting Area

SEP .... Socioeconomic Position

SES .... Socioeconomic Status

ZCTA .... ZIP Code Tabulation Areas

ZIP .... Zone Improvement Plan

CHAPTER 1

INTRODUCTION

The common occurrence of diabetes in the United States continues to be a persistent problem, as evident by the increasing prevalence and elevated incidence of this chronic disease (Centers for Disease Control and Prevention [CDC], 2015). Between 1980 and 2011, the age-adjusted prevalence of diagnosed diabetes increased from 2.8 to 6.4 per 100 adults, whereas, the age-adjusted incidence of diagnosed diabetes increased from 3.5 to 7.6 per 1,000 adults (CDC, 2015). The rate of change in the incidence of diagnosed diabetes has varied within this time period and after reaching its peak in 2008, there appeared to be a slight decline (CDC, 2015). Regardless of this promising downward trend, the burden of this disease continues to be large. An estimated 86 million (37%) U.S. adults aged 20 years or over have elevated blood glucose or hemoglobin A1c levels just below the diagnostic criteria for diabetes (CDC, 2014a). This condition is known as prediabetes and becomes more prevalent with age, affecting about 51% of adults aged 65 years or older (CDC, 2014a). Those with prediabetes have an increased risk of developing type 2 diabetes, thus demonstrating the potential growth in the number of Americans being diagnosed with diabetes in the near future, especially within the aging U.S. population.

The continual rise in the prevalence along with a high incidence of diabetes in the nation corresponds with an increasing economic burden due to the chronic nature of this disease and the devastating occurrence of complications and other comorbid conditions (Ng, Lee, Toh, & Ko, 2014). Nationally, the cost of diabetes increased for both direct medical costs and indirect expenses that resulted from lost productivity and absenteeism at work (American Diabetes Association [ADA], 2013; Ng, Lee, Toh, & Ko, 2014). In 2012, diabetes was estimated to cost the nation $245 billion with about 72% of this cost attributable to direct medical expenses (ADA, 2013). To further exacerbate this growing burden on the economy and the health care system, poor management of this disease can often lead to several micro- and macrovascular complications such as hypo- and hyperglycemia, retinopathy, neuropathy, and heart disease (CDC, 2014a; Chiang et al., 2014). Additionally, it is common for individuals with diabetes to also suffer from additional comorbid conditions that lead to increased health care utilization and hospitalizations (Lkhagva, Kuwabara, Matsuda, Gao, & Babazono, 2012; Struijs, Baan, Schellevis, Westert, & Bos, 2006). Health resource use increases with each additional complication and/or comorbid condition among individuals with diabetes with the greatest utilization incurred among those who also have cardiovascular disease or renal complications (ADA, 2013; Carral et al., 2003; Struijs et al., 2006).

Additionally, the prevalence of diabetes across the nation is disproportionately higher in the Southeastern U.S., possibly due to the geographic clustering of racial/ethnic minorities and elevated age-adjusted obesity levels (Baicker, Chandra, & Skinner, 2005; CDC, 2014a; Shrestha, 2012). The concentration of African Americans in the Southeast is higher than the national average; whereas, Whites are located at higher proportions in the Northeast and the Western U.S. (Baicker et al., 2005). This geographic variation is also evident in the incidence of type 1 and type 2 diabetes among youth registered with the SEARCH for Diabetes in Youth Study (Liese et al., 2010). Additional exploration of these differences has revealed small-area variations for each diabetes type at both the census tract and county level, thus demonstrating a spatial component to the clustering of cases (Liese et al., 2010). Another study observed these small-area variations in diabetes prevalence to be associated with several area-level socioeconomic status (SES) characteristics including education level, income, percentage of single-parent households, unemployment rates, crime level, and number of vacant/placarded dwellings (Green, Hoppa, Young, & Blanchard, 2003). Low SES, rural residence, and minority race/ethnicity were also identified as characteristics associated with an increased risk for developing diabetes (Brancati, Whelton, Kuller, & Klag, 1996; Krishna, Gillespie, & McBride, 2010; Robbins, Vaccarino, Zhang, & Kasl, 2005).

Southeastern U.S. counties are often found to be high-high clusters of diabetes, which are counties with a high prevalence of diabetes surrounded by neighboring counties with similarly high prevalence (Shrestha, 2012). The location of these clusters was found to be associated with SES variables as well as risk factors for type 2 diabetes. Counties with high-high spatial clustering of diabetes were observed to have significantly higher age-adjusted leisure-time physical inactivity and obesity rates compared to areas of non-clustering or low-low clustering (Shrestha, 2012).

South Carolina has a plurality of high-high spatial clusters of diabetes prevalence (Shrestha, 2012) and currently ranks fourth in the nation for diabetes prevalence (South Carolina [SC] Division of Diabetes, Heart Disease, Obesity, and School Health, 2014). In 2012, the age-adjusted prevalence for diagnosed diabetes was 10.6 per 100 adults in South Carolina compared to the national rate of 9.0 per 100 adults (CDC, 2014b). The elevated prevalence of diabetes in this state is disproportionately higher among African Americans, who have the third highest rate of diabetes in the nation for this racial group, with approximately 1 in 6 diagnosed with diabetes (SC Division of Diabetes, Heart Disease, Obesity, and School Health, 2014). Additionally, hospital costs attributable to diabetes increased by 33% between 2009 and 2013 in South Carolina (SC Division of Diabetes, Heart Disease, Obesity, and School Health, 2014). The increasing disparities in diabetes occurrence and the growing economic burden associated complications/comorbid conditions in South Carolina characterizes its vulnerability, which may inadvertently predispose some individuals with diabetes to display differential rates of health care utilization.

Limited accessibility to primary care providers as well as poor disease management may lead many individuals with diabetes to select the emergency department (ED) as their main source of routine medical care. The determinants associated with using the ED as a regular source of health care have been well established and include such factors as demographic characteristics (Cunningham, Clancy, Cohen, & Wilets, 1995; Hong, Baumann, & Boudreaux, 2007; Singal et al., 1992), type of health insurance or lack of insurance (Capp, Rooks, Wiler, Zane, & Ginde, 2013; Cunningham et al., 1995), SES (Cunningham et al., 1995; Hong et al., 2007; O'Brien et al., 1997), access issues (Capp et al., 2013), and neighborhood characteristics (Li, Grabowski, McCarthy, & Kelen, 2003; Lowe et al., 2009). Some of these same factors may also be persistent reasons as to why certain individuals with diabetes are using the ED to treat their disease and its associated complications/comorbid conditions. Additionally, many of these determinants may also display a spatial component similar to the geographic variation evident in diabetes prevalence.

More research is needed to understand the multiple factors associated with why certain vulnerable populations seek routine care in an ED for diabetes. This thesis seeks to evaluate the geographic variation in ED use among patients diagnosed with diabetes in the state of South Carolina using geographical information systems (GIS). Additionally, multilevel models will be used to examine the effects of both individual- and neighborhood-level characteristics associated with frequent ED use among patients with diabetes.

CHAPTER 2

LITERATURE REVIEW

PUBLIC HEALTH SIGNIFICANCE

Individuals with chronic conditions who seek regular medical care in the ED often lack a continuity of care that inadvertently may lead to a higher likelihood of readmission and increased hospitalization (Christakis, Mells, Koepsell, Zimmerman, & Connell, 2001; Jiang, Friedman, Stryer, & Andrews, 2003; Oster & Bindman, 2003; Weissman, Stern, Fielding, & Epstein, 1991). The risk of hospitalization also increases and is significantly longer for patients who delay obtaining care, possibly due to misperceptions of personal health status, financial constraints, scheduling conflicts, or limited access (Weissman et al., 1991). Early intervention and continuity of care is essential for chronic diseases in order to address any complications early as well as reduce the progression of the disease and the deterioration of their health overtime (Clark et al., 2000; Wagner et al., 2001). There are several acute and chronic conditions that have been classified as "ambulatory care sensitive conditions" (ACSC) that are impacted by the timeliness of preventative and/or routine medical care (Torio & Andrews, 2014). Hospitalization for any ACSC has been termed as "preventable hospitalization", indicating that those hospital admissions could have been avoided through timely and effective medical care in an outpatient setting and has become an acceptable indicator of accessibility to primary care (Laditka & Laditka, 2006; Torio & Andrews, 2014).

Diabetes is considered an ACSC due to the debilitating complications and comorbid conditions associated with poor disease management (Ricketts, Randolph, Howard, Pathman, & Carey, 2001). The economic strain of diabetes on the health care system and the continual rise in the prevalence of this disease demonstrates the importance of addressing this growing public health problem. Hospitalization for diabetes and its associated complications is likely among patients who were not properly educated/trained on disease-management as well as among those with poor glycemic control (Fullerton et al., 2014; Kruzikas, Barrett, Coffey, & Andrews, 2004). Furthermore, the number of hospitalizations for diabetes is steadily increasing over the years (CDC, 2015). About 30% of patients with diabetes who are hospitalized within a given year are likely to be readmitted a second time. Additionally, there are noticeable inequalities in these rates with certain vulnerable populations demonstrating a higher rate of multiple hospitalizations due to their age, race/ethnicity, income, and/or primary payer of health care (Jiang et al., 2003).

Also, many visits to the ED for treatment of any ACSC, including diabetes, can be considered avoidable because they often result in hospitalization (Oster & Bindman, 2003). Unfortunately, limited accessibility to primary care has led several individuals to become dependent upon the ED as a substitute setting for receiving routine medical care, with some identifying the ED as their main provider (Billings, Parikh, & Mijanovich, 2000; Habenstreit, 1986; O'Brien et al., 1997). This demonstrates that the role of the ED in the health care system has expanded beyond providing just emergency care to also include the provision of primary care. Moreover, the ED is mandated by law to provide medical care regardless of an individual's insurance status or their ability to pay (Zibulewsky, 2001).

Nationally as well as in the state of South Carolina, there has been an increased utilization of the ED, which contributes to the growing issue of overcrowding within waiting rooms (Pitts, Pines, Handrigan, & Kellermann, 2012; SC Public Health Institute, 2011). Common causes associated with this increased demand in addition to overcrowding include non-urgent visits, frequent ED users, staff shortages, limited number of hospital beds, increased prevalence of chronic diseases, increased duration of occupancy, aging population, and influenza season (Hoot & Aronsky, 2008; Santos-Eggimann, 2002). There are also social and environmental factors that drive certain populations to use the ED as their regular source of care, thus producing an additional strain on the ED (Hong et al., 2007; Li et al., 2003; O'Brien et al., 1997). Some consequences associated with overcrowding include patient mortality, reduced quality of care as a result of delayed treatment and transportation, ambulance diversion, and limited access to emergency care (Hoot & Aronsky, 2008; Richardson & Hwang, 2001).

Additionally, the number of individuals with diabetes seeking medical care in an ED continues to rise (CDC, 2015). Between 2006 and 2009 in the United States, ED visits related to diabetes increased by about 2,280,000 (CDC, 2015). In 2009, the number one primary diagnosis among adults with diabetes aged 18 years or older for visiting the ED was due to complications of the disease followed by nonspecific chest pain and congestive heart failure (CDC, 2015). Age, sex, and racial differences in ED utilization are evident for diabetes-related visits with individuals older than 75 years, females, and African Americans having the highest visit rates within their respective groups (CDC, 2015). The ED is also more likely to treat individuals who live within close proximity to a hospital which often represents the most vulnerable populations (Curtis & Lee, 2010; Lowe et al., 2009; Marco, Weiner, Ream, Lumbrezer, & Karanovic, 2012).

Furthermore, the ED is not a sufficient health care setting for treating diabetes or preventing the complications and comorbid conditions associated with more severe cases of this disease. The complex and chronic nature of this disease warrants a more continuous form of care with consistent follow-ups that provide appropriate treatment to delay the progression of disease severity and deterioration of health, along with preventative care to reduce the likely occurrence of complications (ADA, 2015; Wagner et al., 2001). Optimally caring for individuals with diabetes is difficult given the fragmented delivery of health care and poor coordination between multiple health care settings, thus resulting in variations in the quality of care (ADA, 2015).

High-quality care for any chronic disease requires continuous interaction between the patient and the health care team, an individualized treatment plan that considers the needs of the patient, anticipatory medical care, provision of evidence-based services, and cooperative coordination between multiple health care providers (Wagner et al., 2001). Additionally, self-management support plays a significant role in chronic disease control (Wagner et al., 2001). Individuals with diabetes should receive diabetes self-management education and ongoing support to encourage the maintenance of disease self-management over time (ADA, 2015). Successful application of the chronic care model to diabetes management can produce positive health outcomes (ADA, 2015; Stellefson, Dipnarine, & Stopka, 2013) indicating that long-term management of diabetes is critical and evidently points to the need of effectively reducing the number of individuals with diabetes relying on the ED for routine care.

The disproportion of diabetes prevalence to certain populations reveals an underlying geographic pattern that may also predispose some individuals with diabetes to seek routine care in the ED. Examination of these geographic variations in ED utilization among patients with diabetes is necessary in order to reveal areas where improvements in quality of care, self-management, and accessibility to medical care may be needed. Furthermore, patients with diabetes who reside in South Carolina represent a vulnerable population that may benefit greatly from identifying areas of greatest ED utilization where interventions can be implemented to reduce the likelihood of readmission and improve disease management.

ANDERSEN'S BEHAVIORAL MODEL OF HEALTH SERVICES USE

The variation in health care utilization across different populations and geographic areas has led to the development of conceptual models to identify common social and environmental characteristics that predict an individual's pattern of use. The Andersen's Behavioral Model of Health Services Use has become a widely recognized multilevel model used to explain the "behavioral" process leading to the selection of health services (Andersen, 1968). Application of this model provides a framework for understanding and defining the individual- and neighborhood-level characteristics that may influence health services use in vulnerable populations.

This model has been redefined over the years to include feedback loops to demonstrate the impact that health outcomes can have on subsequent use of health services as well as the inclusion of environmental factors (Andersen, 1995). There is a complex interaction between the environment and population characteristics that may predispose certain populations to utilize health services disproportionately more or less than others. The environmental domain is broken into the health care system and the external environment; whereas population characteristics, is further subdivided into three components: predisposing, enabling, and need-for-care characteristics (Andersen, 1995). The use and adaptation of the Andersen's Behavioral Model to investigate health care utilization has been extensive in the literature as evident by the application of the model to various health care settings, diseases, and populations (Ani et al., 2008; Babitsch, Gohl, & Lengerke, 2012; McCusker, Karp, Cardin, Durand, & Morin, 2003; Shah et al., 2003)

ENVIRONMENT

The differential rates of health care utilization across geographic areas and populations (Baicker et al., 2005) demonstrate the importance of understanding the impact that certain neighborhood-level characteristics have on use of services. Additional conceptual framework models have expanded upon Andersen's Behavioral Model to determine the impact of individual- and neighborhood-level factors on access to health care (Andersen et al., 2002; Davidson, Andersen, Wyn, & Brown, 2004). Neighborhood-level characteristics are aggregated measures reflecting the average population score of individuals residing within a defined geographic area (Andersen et al., 2002). Comprehensive measures to describe the surrounding neighborhood should include variables that describe a neighborhood's demand for care (e.g. percent of low income households, uninsured, and Medicaid beneficiaries), support for services (e.g. income and unemployment rate), health structure (e.g. physician supply per capita), and dynamics of the health market (Andersen et al., 2002). The application of this extended framework of Andersen's Behavioral Model to ED utilization may help to identify underserved populations who routinely seek care in the ED.

The influence of neighborhood-level factors on ED utilization is evident within the literature. The elevated demand for health care in the nation has resulted in the increased use of ED services with some geographic areas displaying disproportionately higher rates as a result of variations in demographic and housing ownership characteristics (Cunningham, 2006; Li et al., 2003). ED utilization increased significantly within an urban neighborhood as the racial composition shifted from an equally representative racial distribution to a predominantly African American neighborhood (Li et al., 2003). Furthermore, neighborhoods with a greater proportion of female residents and renter-occupied/vacant housing units were significantly more likely to demonstrate elevated rates of ED visits (Li et al., 2003). Distance decay is another important determinant of ED use with the highest visit rates demonstrated among those living less than a half a mile of the ED to within a 10 minute drive (Li et al., 2003; Lowe et al., 2009; Mathison et al., 2013; Parker & Campbell, 1998). The concept of distance decay indicates that ED utilization rates are also likely to vary within a defined geographic area given the differential distances from residences to the ED.

Additionally, the neighborhood's inability to support primary care services may result in higher ED utilization. Elevated patterns of ED use are observed in low income neighborhoods and ED revisit rates tend to be 25% higher among patients who reside in poorer areas as compared to wealthier neighborhoods (Billings et al., 2000; Mathison et al., 2013; Steiner, Barrett, & Hunter, 2010). Areas with a higher proportion of uninsured residents and immigrants also demonstrate increased rates of ED utilization with some neighborhoods displaying differential rates of accessibility issues among uninsured individuals, therefore potentially hindering their ability to obtain primary care (Billings et al., 2000; Cunningham & Kemper, 1998; Habenstreit, 1986; Steiner et al., 2010). The underlying racial and ethnic composition of a neighborhood's uninsured population is one of the most important predictors accounting for these differences among individuals who report difficulties with obtaining health care (Cunningham & Kemper, 1998). A region's rural/urban status is another predisposing environmental factor. Rural residents display higher rates of ED utilization compared to those in urban areas, possibly due to limited accessibility to primary care (Haggerty, Roberge, Pineault, Larouche, & Touati, 2007; McCusker et al., 2010; Steiner et al., 2010). The vulnerability of these subgroups demonstrates that the location of residence is an important determinant of health care accessibility which may restrict an individual's ability to access the primary care system, thus potentially increasing their dependence on the ED for routine care.

Whereas, increased accessibility to primary care has been demonstrated to produce the opposite effect indicating that a neighborhood's health care structure also impacts ED utilization. ED use is significantly less among Medicaid beneficiaries who are able to access their primary care providers more readily as a result of extended evening and weekend hours (Lowe et al., 2005). Additionally, there were significantly fewer number of ED visits among Medicaid enrollees living within neighborhoods that had a greater primary care capacity (Lowe et al., 2009). While, limited appointment availability and accessibility to primary care providers due to limited office hours were the most common reasons for individuals using the ED for non-urgent visits (Vayda, Gent, & Hendershot, 1975). Furthermore, non-urgent ED visits increased in relation to decreased spatial density of primary care providers (Mathison et al., 2013). Exposure to these neighborhood-level characteristics may increase or decrease an individual's dependence upon the ED for routine care; however, it is important to consider the interaction of these aggregate measures on the individual-level characteristics of the patient and their decision making process of where to obtain care.

POPULATION CHARACTERISTICS

Routine use of the ED for medical care may be an indicator of reduced access to primary care thus demonstrating a contextual factor that emphasizes the concept that location of residence matters. However, it is also important to consider the individual-level characteristics that may predispose certain populations to utilize health care resources more than others. The Andersen's Behavioral Model has grouped these characteristics into three major components: predisposing, enabling, and need-for-care (Andersen, 1995). The differential rates of ED utilization may be explained partially by the combined effects of these components, which is evident in the literature when this framework is applied to understanding these variations.

Predisposing Characteristics

The existence of certain characteristics prior to the onset of an illness/injury may predispose certain individuals to seek or delay receiving care for their condition (Bazargan, Johnson, & Stein, 2003; Shah et al., 2003). These predisposing characteristics include demographic (e.g. age, race, and sex), social (e.g. education level, employment status, and ethnicity), and mental (e.g. health beliefs) factors (Babitsch et al., 2012). The literature examining the predisposing characteristics of elevated patterns of ED utilization has demonstrated age to be an important predictor (Aminzadeh & Dalziel, 2002; McCusker et al., 2003). The increasing ED utilization within the United States may be a result of the rapidly aging population and the increasing prevalence of chronic disease among the elderly (CDC, 2013; Santos-Eggimann, 2002). Older adults use the ED at higher rates in comparison to the general adult population and about one third to one half of those ED visits results in hospitalization (Aminzadeh & Dalziel, 2002). Additionally, repeat visits to the ED are a likely occurrence among older adults who live alone, are male, or have multiple functional limitations (McCusker, Healey, Bellavance, & Connolly, 1997). A positive linear relationship has been observed between age and ED use indicating an increased dependence of older adults on the ED for care in both males and females (Murphy & Hepworth, 1996).

Also, the direction of the association between age and utilization of the ED will differ depending on the characteristics of the population studied. When examining usual source of ambulatory care, adults between the ages of 18 to 64 years were more likely to report the ED as their primary source of medical care and display higher rates of ED revisits compared to those older than 65 years (Hong et al., 2007; O'Brien et al., 1997; Steiner et al., 2010; Walls, Rhodes, & Kennedy, 2002). This contrasting finding may partly be explained by the increased need-for-care among older adults when access to health care is considered equitable, which is why need-for-care has been defined as the most important determinant of ED utilization in older adults (McCusker et al., 2003). On the other hand, the opposite relationship observed among those who identify the ED as their regular source of care may partially be explained by restricted accessibility to primary care (McCusker et al., 2003). Furthermore, those who identify the ED as their regular source of care represent a small proportion of the total number of patients treated in the ED (Walls et al., 2002) and therefore, may be impacted differently by certain predisposing factors.

Additionally, a greater proportion of males were observed to use the ED more in one study comparing two hospitals located within the same city (Vayda et al., 1975). Whereas among regular ED users, the findings are conflicting in regards to which gender is more likely to identify the ED as their usual source of care (Baker & Baker, 1994; Hong et al., 2007; Walls et al., 2002). Also, African American and Hispanic patients display a higher likelihood of using the ED for routine health care and are more likely to have a non-urgent ED visit in comparison to White patients (Baker & Baker, 1994; Hong et al., 2007; Walls et al., 2002). The combined effects of predisposing characteristics and need-for-care can also lead to increased ED utilization as evident among African Americans suffering from chronic ACSC (Oster & Bindman, 2003). A lack of access to outpatient care following an ED discharge for a chronic ACSC among African Americans may explain some of the variations in their elevated rates (Oster & Bindman, 2003), which demonstrates that transitioning between different health care settings may reduce the continuity of care and lead to an increased risk for readmission as a result of deterioration in health.

Additional significant predictors for using the ED as a usual source of care include rural residence and less than a college education (Baker & Baker, 1994; Walls et al., 2002). Furthermore, there are several health beliefs that predispose certain populations to regularly use the ED. A common perceptual factor resulting in increased likelihood of ED utilization includes the belief that an ED visit is free or cost less than/or equal to a visit in a primary care setting (Habenstreit, 1986; Hong et al., 2007; O'Brien et al., 1997). African American and Hispanic patients were more likely to display this perception (Hong et al., 2007). Other perceptual factors include the beliefs that the ED offers higher quality care and has additional resources available in comparison to a primary care setting (Hong et al., 2007; O'Brien et al., 1997). Hispanics displayed this perception about the ED more than any other racial group; while African Americans were less likely to believe this (Hong et al., 2007). Lastly, those who are frequent ED users were more likely to believe that their medical issues would be addressed faster and therefore, they were more willing to wait an average of four hours for a visit than for a scheduled appointment in a primary care setting (Hong et al., 2007; O'Brien et al., 1997).

Enabling Characteristics

Enabling characteristics refer to the ability of an individual to obtain care when necessary and includes the presence of both individual- and neighborhood-level resources (Andersen et al., 2002; Bazargan et al., 2003; Shah et al., 2003). The degree of mutability of these characteristics is considered high indicating the potential for change by way of implementing policies or interventions to elicit improvements in access to care and disease management (Andersen et al., 2002; Andersen, 1995). The enabling characteristics at the personal level are dependent upon an individual's resources to pay for care as well as their knowledge of how to access the necessary health services required for treatment of their condition (Andersen, 1995). Some common enabling characteristics identified in the literature include income, health insurance, education level, social support, employment status, and having a regular source of care (Babitsch et al., 2012).

Patients who reported the ED as their regular source of care were more likely to be uninsured or a Medicaid beneficiary, unemployed, have an annual income less than $30,000, and/or report a lower level of social support (Hong et al., 2007; O'Brien et al., 1997; Walls et al., 2002). Of these predictors of regular ED use, insurance type was observed to be the strongest (Hong et al., 2007). Comparisons between insurance types reveal that Medicaid beneficiaries have a higher likelihood of reporting the ED as their regular source of care and are more likely to have the highest rates of ED revisits (Baker & Baker, 1994; Steiner et al., 2010). Additionally, Medicaid recipients also display a disproportionately higher rate of ED utilization for chronic ACSC and are less likely to receive follow-up care after ED discharge (Oster & Bindman, 2003). Enabling factors that predispose older adults to utilize the ED also includes lack of social support as well as access to a regular source of health care (McCusker et al., 2003).

The relationship between race/ethnicity and regular ED use explained in the preceding section was attenuated to non-significance when several SES factors were accounted for including education, health insurance, employment status, and annual income (Hong et al., 2007). However, these findings are conflicting when both race/ethnicity and other SES variables are included in the same model to predict regular ED use. One study found annual income to be a better predictor for regular ED use than race/ethnicity (O'Brien et al., 1997); whereas, another study demonstrated race/ethnicity to be a significant predictor while insurance status and education levels failed to reach significance within the same model (Baker & Baker, 1994). The majority of these SES factors are considered enabling characteristics and when insufficient measures are used to account for these factors, residual confounding tends to be apparent (Bazargan et al., 2003). The observed confounding effects of SES on the relationship between race/ethnicity and regular ED use are partly due to the correlation between these two variables. African Americans and Hispanics who use the ED for routine care are more likely to be disadvantaged as evident by the higher proportions of no insurance, low education, unemployment, and poverty levels in this racial group as compared to their White counterparts (Hong et al., 2007). The observed disparities in ED use between racial/ethnic classes may partly be explained by SES and demonstrates the importance of accounting for this enabling factor.

Need-for-care Characteristics

In the initial Andersen's Behavior Model, the need-for-care characteristics preceded the use of health services indicating that perceived and evaluated health status of an individual is necessary in order to elicit action to obtain care (Andersen, 1995; Bazargan et al., 2003). Self-perceived need represents the individual's opinion of their own health status while evaluated need is based on a professional assessment of their overall health (Andersen, 1995; Babitsch et al., 2012). Common need characteristics in the literature include evaluated and/or perceived health status, presence of chronic disease (e.g. diabetes, hypertension, heart disease, or cancer), number of comorbidities or prior medical conditions, previous ED visit, and risk factors (e.g. obesity, smoking, etc.) (Babitsch et al., 2012; McCusker et al., 2003).

The use of the ED for non-urgent health problems was more likely among those with better perceived health status and a lower perceived severity of their current medical issue as compared to their urgent/semi-urgent counterparts (Afilalo et al., 2004). About one fourth of these non-urgent ED users report perceived need as the reason for not seeking care in a primary care setting; whereas in another study, cost became the major determining factor for relying on the ED for medical care (Afilalo et al., 2004; Habenstreit, 1986). Perceived health status was also not a significant predictor of ED utilization among regular ED users, possibly because they are less likely to report having a chronic disease or state that they were "too sick or hurt/injured to go elsewhere" (Baker & Baker, 1994; Hong et al., 2007; O'Brien et al., 1997; Walls et al., 2002). Whereas, among those regular ED users who do have a chronic disease, clinics became the primary source for treating their condition and primary care settings were predominantly used for other more serious illnesses instead of the ED (Habenstreit, 1986). This may be due to the prolonged waiting times in the ED which has been identified as a major deterrent for using this health care setting to treat more serious health issues that have symptoms of severe pain or sickness (Habenstreit, 1986). Also, this demonstrates that perceived severity of a health condition may have a greater impact on dictating where regular ED users will seek care indicating that the more serious the health condition, the more likely alternative sources of care are utilized if the necessary resources are available.

Among older adults, ED visits increased with age in both males and females (Murphy et al., 1996). Additionally, the rates of utilization and repeat visits to the ED are significantly higher in older adults compared to younger individuals (Aminzadeh & Dalziel, 2002). The distinct patterns of health services use differentiates this age group from their younger counterparts primarily because of the predominant role that the need-for-care characteristics play in predicting utilization (Aminzadeh & Dalziel, 2002; McCusker et al., 2003; Wolinsky & Johnson, 1991).

Both perceived poor health and evaluated need, as measured by the number of comorbidities or diagnosed conditions, are significant predictors of ED use among older adults as well as early and frequent returns to the ED (McCusker, Cardin, Bellavance, & Belzile, 2000; McCusker et al., 2003; Shah, Rathouz, & Chin, 2001). Furthermore, older adults with a greater number of comorbidities or a higher comorbidity index score were more likely to use the ED in comparison to younger individuals (Chi, Wu, Chan, & Lee, 2009; Shah et al., 2001). The medical diagnoses that significantly predict use of the ED among older adults include heart disease, diabetes, stroke, depression, falls, visual impairment, and abdominal pain (McCusker et al., 2000, 2003; Samaras, Chevalley, Samaras, & Gold, 2010). Also, reduced physical functioning, impaired cognition, and increased deficiencies in activities of daily living were significantly associated with elevated rates of ED utilization (Chi et al., 2009; McCusker et al., 2000; Shah et al., 2001). Additionally, those who visited the ED in the previous month or were hospitalized in the last six months were more likely to return early and more frequently to the ED (McCusker et al., 2000).

The role of need characteristics in predicting ED utilization will depend on the sub-population studied. Individuals who identify the ED as their usual source of care display a different set of needs that predispose them to seek care in the ED; whereas among older adults, both perceived and evaluated needs are significant predictors of ED utilization. The differences between ED utilization among populations may partly be explained by the combined effects of predisposing, enabling, and need characteristics.

Application of the Andersen's Behavior Model to other vulnerable populations utilizing the ED for care is warranted in order to gain an understanding of why certain individuals are relying on this particular health care setting. Patients with diabetes are a medically vulnerable population because of the chronic nature of their condition and the incessant occurrence of complications and comorbid conditions (Broyles, McAuley, & Baird-Holmes, 1999). Among older adults, a history of diabetes is a significant predictor of frequent returns to the ED over the course of a six month period (McCusker et al., 2000). In another study, preventable complications attributed to about one fifth of the ED visits among patients with diabetes and they were four times more likely to be hospitalized following an ED visit, further demonstrating the vulnerability of this population (Murphy, Faulkenberry, Rumpel, & Wheeler, 1985).

Additionally, the disproportionate burden of this disease occurs more commonly in vulnerable neighborhoods with a higher proportion of minority, lower education and income levels, greater number of single-parent households and vacant/placarded dwellings, and higher unemployment and crime rates (Green et al., 2003). Furthermore, individuals of low SES, minority race/ethnicity, or rural residency have a higher risk for diabetes (Brancati et al., 1996; Krishna et al., 2010; Robbins et al., 2005). Like characteristics were also found among individuals who displayed higher rates of emergency department (ED) utilization indicating the possibility that similar individual- and neighborhood-level characteristics of frequent ED use may be prominent determinants among individuals with diabetes.

Disparities in ED use among patients with diabetes exist in the literature. At the individual-level, the literature has demonstrated common predisposing, enabling, and need-for-care characteristics that predict ED utilization among patients with diabetes. There is a disproportionately higher tendency to use the ED for care among patients with diabetes who are younger, African American, less educated, and of female gender (Bazargan et al., 2003). Similarly, among older Medicare beneficiaries with diabetes, African Americans, less educated, and female patients were more likely to use the ED in comparison to their respective counterparts (Chin, Zhang, & Merrell, 1998). Furthermore, in a stratified analysis by race and gender, older African American women on Medicare had significantly higher rates of ED utilization compared to White women (Chin et al., 1998).

Age is another significant predictor of ED utilization as evident by how older adults with diabetes display a higher likelihood of frequent returns to the ED (McCusker et al., 2000). Age was found to modify the relationship between First Nation status (Aboriginal population) and ED visit rates among patients with diabetes residing in Canada (Capp et al., 2013). The disparity in ED and hospital utilization between First Nations with diabetes and Non-First Nations increased drastically with age subsequently leading to a six times higher rate of ED use among First Nations after the age of 80 (Capp et al., 2013). The presence of this effect modifier demonstrates the complexity of predicting patterns of ED utilization and therefore, indicates the necessity for considering possible interactions.

Among patients with diabetes, accessibility to care seems to be a prominent enabling characteristic of ED utilization. This is evident with how older African

American Medicare beneficiaries with diabetes were less likely to report satisfaction with the ease of seeing their primary care provider indicating the possible presence of barriers to receiving care in this setting (Chin et al., 1998). On the other hand, lower rates of ED visits were observed among African Americans and Hispanics with diabetes who participated in a county funded program designed to improve health care accessibility among low income individuals (Bazargan et al., 2003). Type of health insurance is another enabling characteristic that impacts ED utilization. This was demonstrated among frequent ED users with Medicaid insurance in which diabetes was the third most common chronic condition listed as a diagnosis on medical records (Capp et al., 2013).

The availability of resources is another enabling characteristic that may impact an individual's ability to pay for the care required. Diabetes is a very costly condition and one study found that out-of-pocket expenses were a significant barrier to obtaining medical care (Fox & Grandy, 2008). The majority of the participants with type 2 diabetes (82%) in this study had health insurance that covered a portion of the cost for medical supplies; however, out-of-pocket expenses prevented about one third of the participants with type 2 diabetes from obtaining the necessary supplies and prescribed medications (Fox & Grandy, 2008). This indicates that the ability to adequately manage diabetes may inadvertently be impacted by an individual's SES and insurance coverage, which may or may not lead to future complications and comorbid conditions that subsequently impacts health care utilization (Pilkington et al., 2010).

At the neighborhood-level, one study compared rates of hospitalization and ED use among geographically defined health zones in Duval County, Florida and found that the urban core of the county displayed a disproportionately higher rate of diabetes-related

ED visits (Livingood et al., 2010). Residents of this health zone were more likely to be African American, less educated, and poorer in comparison to the other health zones. The vulnerability of these subgroups demonstrates that residence is an important determinant of accessibility to primary care, thus potentially increasing their dependence on the ED for routine care.

Additionally, the neighborhood in which an individual with diabetes lives may impact their ability to manage their disease. Those who live in low income neighborhoods are more likely to display poor disease management as demonstrated by elevated hemoglobin A1c levels (Geraghty, Balsbaugh, Nuovo, & Tandon, 2010). Also, patients with diabetes who live in close proximity to their primary care provider are more likely to adhere to their treatment plan for insulin administration (Geraghty et al., 2010). These neighborhood-level characteristics indicate that the environment in which an individual lives can have a significant impact on their ability to self-manage as well as whether they use the ED for care as a result of complications associated with poor disease management.

The complexity and chronic nature of diabetes warrants a more continuous form of care indicating that the need for care is present among individuals with diabetes. A history of diabetes is considered to be a need factor and has been found to increase the tendency of seeking medical care among patients suffering from this condition (Babitsch et al., 2012; Broyles et al., 1999). A possible reason for an increased propensity toward elevated use of health services may partly be due to the presence of both perceived and evaluated needs. Patients with diabetes were more likely to self-report poor to fair perceived health which may explain the increased ED utilization because of the positive association between perceived health status and health services use (Broyles et al., 1999). Additionally, self-administration of insulin via injection and the number of diabetes-related complications were significant need-for-care characteristics predicting ED utilization among minority patients with diabetes (Bazargan et al., 2003).

One would think that need for care would be the most important determinant of ED utilization among patients with diabetes; however, one particular study found that the predisposing characteristics (i.e. age, education, gender, and ethnicity) of a minority population explained about the same amount of variance in the model as the needs characteristics (Bazargan et al., 2003). Although the need for care is present in this medically vulnerable population, there may be other characteristics at the individual- and neighborhood-level that play a significant role in predicting ED utilization.

SUMMARY

The ED is not a sufficient health care setting for treating diabetes or preventing its complications and comorbid conditions because of the necessity for continuous medical care. The increasing number of diabetes-related visits nationwide in the ED warrants attention because of the lack of continuity of care received in this setting along with the associated increased likelihood of hospitalization and readmission (CDC, 2015; Jiang et al., 2003). The literature examining ED use among patients with diabetes has often examined the association between utilization rates with individual- (Bazargan et al., 2003; Capp et al., 2013; Chin et al., 1998; McCusker et al., 2000) and neighborhood-level (Kruzikas et al., 2004; Livingood et al., 2010) characteristics separately. Given the geographic differences in ED utilization among patients with diabetes and the significant individual- and neighborhood-level characteristics associated with use, additional research is need to examine this relationship spatially using GIS and multilevel modelling.

GIS is used extensively in the literature to examine the distribution of health care and disease (Cromley, 2003; McLafferty, 2003). Furthermore, geographic variations in diabetes prevalence (Green et al., 2003; Livingood et al., 2010), diabetes-related adverse outcomes (Geraghty et al., 2010), diabetes rates and medical resources/resource use (Curtis, Kothari, Paul, & Connors, 2013), and non-urgent ED utilization among pediatric patients (Mathison et al., 2013) have been investigated using GIS. Additionally, Livingood and colleagues (2010) have also applied GIS mapping to identify areas with high rates of diabetes-related ED use and hospitalizations in Duval County, Florida (Livingood et al., 2010). However, the authors created health zones by combining multiple adjacent ZIP codes together. The aggregation of ZIP codes may be considered a limitation that will likely mask the presence of small-area variations that may exist at the ZIP code level. Also, the data source for this study used ED and hospital discharge data to identify all diabetes-related visits for the year of 2007. Their final dataset likely contained multiple records for some of the same patients especially if they had used the ED more than once.

This thesis will add to the body of literature by using unique patient ID numbers to create a dataset that contains one record for each patient along with their demographic and spatial information. Further improvements will be made by including additional neighborhood-level characteristics that provide information about the SES of their neighborhood in order to identify other determinants related to the environment that may predispose certain patients with diabetes to use the ED. Additionally, this thesis will examine the effects of both individual- and neighborhood-level characteristics associated with frequent ED use among patients with diabetes.

CHAPTER 3

METHODOLOGY

RESEARCH AIM AND QUESTIONS

This study aimed to evaluate the geographic variation in diabetes-related ED use among patients diagnosed with diabetes in South Carolina using GIS and to illuminate important individual- and neighborhood- level (i.e., ZIP Code Tabulation Areas/ZCTAs) determinants of diabetes-related ED utilization.

Question 1: Is there evidence of spatial clustering/dispersion of diabetes-related ED utilization among patients diagnosed with diabetes in South Carolina?

Question 2: What neighborhood-level characteristics are associated with increased ZCTA ED utilization rates?

Question 3: What individual- and neighborhood-level characteristics are associated with frequent ED use among patients with diabetes in South Carolina?

DATA SOURCES

ED Discharge Data

Civilian hospitals in the state of South Carolina are mandated to report all ED visits with patient and provider identifiers to the South Carolina Revenue and Fiscal Affairs Office (RFA – formerly called the Office of Research and Statistics). In 2009, each ED visit reported to the RFA began using a unique identifier for each patient, which allows for record matching across multiple providers. This unique ID was used in this present study to identify patients with diabetes who used the ED for medical care in 2013. The RFA has standardized the primary and secondary diagnoses for each ED visit using the International Classification of Diseases Version 9 (ICD-9) codes so that comparisons could be made across multiple years. ICD-9 codes were used to compile diabetes-related ED visits from a dataset containing all ED discharge data in the state of South Carolina during the year 2013. Since this subset likely contained multiple records for some of the same patients, the unique patient ID numbers were used to extract each patient's first visit that occurred between January 1, 2013 and December 31, 2013. The total number of visits that occurred within the year 2013 was calculated for each unique patient ID number and served as an indicator of frequency of ED use. Also, each patient with diabetes was categorized as either a non-frequent (one to two ED visits over 12-month period) or a frequent ED user (three or more ED visits over 12-month period).

A total of 174,991 diabetes-related ED visits were identified for the year 2013 and using the unique patient ID numbers, a total of 93,360 patient records were extracted. Patient demographic and spatial characteristics contained in each record included age, sex, race, mailing address ZIP code, and county of residence. Primary source of payment was also provided on each patient record and this information served as an indicator of insurance status. The characteristics recorded on the patient's first visit in 2013 was used in this analysis to eliminate any possible inconsistencies occurring during the recording of patient characteristics by multiple providers for those who utilized the ED more than once in 2013.

U.S. Postal Service ZIP Code Coordinates

The centroids for each residential ZIP code in South Carolina were obtained from the South Carolina Department of Health Structured Query Language Server Enterprise Geodatabase (South Carolina Department of Health and Environmental Control [SC DHEC], 2013). Any ZIP codes with a classification code pertaining to a post office (PO) box were excluded from this study because of the possibility of misclassifying patients with diabetes to the incorrect ZCTA-level attributes (n = 1,493 patients) (Hurley, Saunders, Nivas, Hertz, & Reynolds, 2003). Additionally, patient records containing a missing ZIP code, out-of-state ZIP code, or an inappropriate ZIP code digit entry due to human error were excluded (n = 3,351 patients).

Population size and Socio-demographic Data for ZCTAs

The geographical boundaries for each ZCTA located in South Carolina were obtained from the 2010 U.S. Census and imported as a polygon shapefile (United States [U.S.] Census Bureau, 2010a). The ZCTA-level attributes were obtained from the American Community Survey (ACS) five-year estimates for 2013 and included population size, demographic characteristics (i.e. distribution of age, sex, and race), and socioeconomic characteristics (i.e. health insurance, employment, educational attainment, poverty, occupancy characteristics of housing units, occupants per room, non-car ownership per household, and household and family structure) (U.S. Census Bureau, 2013). In the first manuscript, the proportion of housing units designated as being located in a rural/urban area were obtained from the 2010 U.S. Census for each ZCTA (United States Census Bureau, 2010b). Whereas, in the second manuscript, each ZCTA was designated as either rural or urban based on the ZIP code Rural-Urban Commuting Area

Codes (RUCAs) assigned to the ZIP code(s) located within the geographic boundaries of their respective ZCTA polygon (WWAMI Rural Health Research Center, 2007). The Townsend Material Deprivation Index was used as a measure of neighborhood SES and was calculated for each ZCTA using the following 2013 ACS variables: percent of unemployed residents over the age of 16 years, percent of households with more than one person per room, percent of households with no vehicle, and percent of rented-occupied housing units (Townsend, Phillimore, & Beattie, 1988). A high score for the Townsend Deprivation Index was indicative of greater material deprivation. For the maps that were created in GIS, differences in population density were accounted for by dividing the frequency of patients with diabetes who utilized the ED for a given ZCTA by the five-year 2013 estimate of the total number of individuals residing within each ZCTA.

STUDY POPULATION

Exclusion and Inclusion Criteria:

The study population for this thesis included all residents of South Carolina who received medical treatment for diabetes in an ED in the year 2013. For an ED visit to be considered, either the primary diagnosis or one of the 14 additional secondary diagnoses had to have an ICD-9 code of 250.xx (inclusive). All visits with an ICD-9 code of 648.0 or 648.8 were excluded from this analysis in order to prevent the inclusion of ED visits related to pregnancies with gestational diabetes or pre-existing diabetes (n = 617 visits). Additionally, any visit with a major/minor diagnostic level associated with pregnancy, complications of pregnancy, or routine infant/child checkups were excluded (n = 200 visits). Visits that had missing important demographic information such as sex, race, or ID number were excluded as well (n = 68 visits).

STRENGTHS AND LIMITATIONS OF DATA SOURCES

Emergency discharge data has several strengths. This dataset contains visit records for every patient who visited a civilian hospital in South Carolina which provides an opportunity to examine geographic variations in ED utilization. The addition of the unique patient IDs has enhanced the capabilities of this data source to match records between multiple hospitals as well as capture patterns of ED utilization over time.

However, there are several limitations that should be considered. The accuracy of the data obtained for each ED visit is affected by the ability of the individual who collected the information contained within each visit record and therefore, errors in data entry are likely. Since ICD-9 codes were used to extract diabetes-related visits, there is also the possibility of misclassifying patients as not having diabetes, if they did not verbally communicate a pre-existing history of diabetes to medical staff or if they did not receive laboratory bloodwork to measure blood glucose levels for diagnostic purposes. For this thesis, all ICD-9 codes for each of the 14 diagnoses were assumed to have been coded accurately.

Furthermore, the accuracy of the fifth digit of ICD-9 codes is low which limits the ability to distinguish between type 1 and type 2 diabetes. This thesis, therefore, combined the two types. Also, the individual visit records do not contain information on the length of time a patient has had diabetes, which may impact ED utilization because their individual need-for-care is likely to increase with duration of diabetes as a result of complications/comorbid conditions. Additionally, SES of the patient is not available on ED discharge medical records. Lastly, since aggregated data was used as a measure of neighborhood-level characteristics, there is the limitation of ecological fallacy.

STUDY PROTOCOL FOR SPATIAL ANALYSIS

Each patient record contains a ZIP code based on the patient's mailing address. Because ZIP codes change periodically, the latitude and longitude coordinates of each ZIP code centroid were spatially joined to a ZCTA polygon from the 2010 U.S. Census using ArcGIS software, Version 10.2.2 for Windows (Environmental Systems Research Institute, Redlands, CA). After performing this spatial join, each of the 323 residential ZIP codes in South Carolina contained a 5-digit ZCTA. An additional join was performed between the ZIP code database and the diabetes-related ED discharge data set so that each patient record contained both a ZIP code and a 5-digit ZCTA. The frequency of unique patient records was calculated for each ZCTA and then standardized using the population sizes obtained from the 2013 ACS five-year estimates. ZCTAs with less than 10 patients with diabetes were excluded due to small samples size. Chloropleth maps were developed to display the population standardized frequencies and the average number of ED visits per patient with diabetes using the North American Datum (NAD) 1983 State Plane Coordinate System for South Carolina (feet) projection.

SPATIAL AND STATISTICAL ANALYSES

GIS mapping within ArcGIS Version 10.2.2 (Environmental Systems Research Institute, Redlands, CA) was used to visually examine spatial patterns of clustering/dispersion in the density of ED patients with diabetes per 100 persons, as well as the average number of ED visits per patient with diabetes across ZCTAs. Data analysis was performed at the ZCTA level using ArcGIS spatial analysis tools including Moran's I coefficient with row standardization to assess the spatial autocorrelation of the density of ED patients with diabetes per 100 persons and the average number of ED visits per patient with diabetes (Moran, 1950). Further analysis was performed to test for spatial clustering of high values (hot spots) and low values (cold spots) across South Carolina using Getis-Ord Gi* (Getis & Ord, 1992). Due to the large variation in the size of ZCTA polygons within South Carolina, spatial relationships between neighboring ZCTAs was conceptualized for both tools using Fixed Distance Band option with the neighborhood search threshold set at the default of 79,581.99 U.S. feet.

All statistical analyses were performed in SAS Version 9.3 (SAS Institute Inc., Cary, NC). In the first manuscript, the demographic characteristics of the ZCTAs were generated and reported as means and standard deviations for continuous variables, and frequencies and proportions for categorical variables. The outcome variables included the standardized frequency of ED patients with diabetes per 100 persons and the average number of ED visits per patient with diabetes. The explanatory variables included several neighborhood-level characteristics which were categorized into quartiles. Correlations were calculated to determine if there was an association between the outcome variables and each of the neighborhood-level characteristics. Additional comparisons by neighborhood-level characteristics were performed to determine if there was a significant difference between quartiles. Following the identification of significant hot and cold spots, descriptive statistics were calculated to compare the neighborhood-level characteristics between significant hot/cold spots with non-clustered areas for both outcome variables. Statistical significance was set at $p \leq 0.05$.

In the second manuscript, means and standard deviations for continuous variables and frequencies and proportions for categorical variables were calculated and reported for the predictor variables at both the individual- and neighborhood-levels. To evaluate the effects of both individual- and neighborhood-level characteristics on frequent ED use among patients with diabetes, a multilevel statistical analysis was performed. The ED discharge dataset contains two-level hierarchical data where patients are nested within ZCTAs. The clustering of patients with diabetes within ZCTAs could result in residual confounding due to similarities between patients in the same ZCTA; thus, a multilevel model was produced to account for this effect. The individual patients were the level-1 units and ZCTAs were the level-2 clusters in this analysis. The outcome variable was dichotomized as non-frequent ED user (one to two ED visits) or frequent ED user (three or more ED visits) and the explanatory variables included both patient-level demographic characteristics (i.e. age, sex, race, and primary source of payment) and neighborhood-level SES and rural/urban designation. Continuous explanatory variables were centered on the grand mean in order to help with model convergence.

Model building was performed by specifying five different models that sequentially became more complex. The first model represented the unconditional means model comprising of just a neighborhood-level random intercept and no predictors. This model was extended to include all of the individual-level predictors as fixed effects in Model 2: age (centered on the grand mean), sex, race (i.e. White, African American, or other), and primary source of payment (i.e. self/indigent, Medicaid, Medicare, private insurance, or other). Preliminary review of the data revealed a possible interaction between race and sex which led to the inclusion of this cross-product interaction as a fixed effect in Model 3. Neighborhood SES as determined by Townsend Material Deprivation Index (grand mean centered) was added to Model 4 followed by rural/urban designation of the neighborhood in Model 5 as fixed effects. The most parsimonious model was selected based Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC). The median odds ratio (MOR) was estimated for each model in order to quantify the amount of variation between ZCTAs (Larsen, Petersen, Budtz-Jorgensen, & Endahl, 2000; Merlo et al., 2006). Data was analyzed using SAS software, Version 9.3 for Windows (SAS Institute, Cary, NC; PROC GLIMMIX based on the LAPLACE estimation method) and all analyses used an alpha level of 0.05 (Raudenbush, Yang, & Yosef, 2000).

CHAPTER 4

MANUSCRIPT 1- NEIGHBORHOOD-LEVEL DETERMINANTS OF EMERGENCY DEPARTMENT UTILIZATION AMONG PATIENTS WITH DIABETES IN SOUTH CAROLINA, 2013[1]

[1] Breneman, CB, Wang, X, & Eberth JM. To be submitted to Social Science and Medicine.

ABSTRACT

Background

The utilization of the emergency department (ED) continues to rise, with certain geographic areas displaying disproportionately higher rates as a result of variations in demographic and socioeconomic characteristics of the neighborhood. This study was designed to identify the neighborhood-level determinants that may predispose certain individuals with diabetes to use the ED in South Carolina.

Methods

ED discharge data for patients with diabetes who utilized the ED in 2013 were geocoded based on their residential ZIP code using Geographic Information Systems (GIS). The boundaries for each neighborhood were defined by U.S. Census Bureau ZIP Code Tabulation Areas (ZCTAs) and the demographic and socioeconomic characteristics describing each ZCTA were obtained from the 2013 American Community Survey five-year estimates. Population standardized density of ED patients with diabetes (No. of patients with diabetes per 100 persons) as well as the average number of ED visits per patient with diabetes were calculated for each ZCTA and analyzed for spatial patterns and non-spatial correlations with neighborhood-level determinants.

Results

A total of 350 ZCTAs were included in this analysis along with a sample size of 91,461 ED patients with diabetes who accumulated over 166,905 visits to the ED in 2013. The standardized density of ED patients with diabetes as well as the average number of ED visits per patient with diabetes varied significantly within neighborhood-level characteristics and were spatially clustered to certain geographic locations (i.e.

Upstate region) within South Carolina. Indicators of low socioeconomic status and family structure were significantly correlated with a higher density of patients with diabetes and an elevated number of ED visits among patients with diabetes.

Conclusion

Exposure to adverse neighborhood-level characteristics may increase an individual's dependence upon the ED for routine care, and therefore, necessitates the need to target neighborhoods with high ED utilization among individuals with diabetes.

INTRODUCTION

The common occurrence of diabetes in the United States continues to be a persistent problem, which is evidenced by the increasing prevalence and incidence of this chronic disease (Centers for Disease Control and Prevention [CDC], 2015). Between 1980 and 2011, the age-adjusted prevalence of diagnosed diabetes increased from 2.8 to 6.4 per 100 adults; whereas, the age-adjusted incidence of diagnosed diabetes increased from 3.5 to 7.6 per 1,000 adults (CDC, 2015). Additionally, an estimated 86 million (37%) U.S. adults aged 20 years or over have elevated blood glucose or hemoglobin A1c levels just below the diagnostic criteria for diabetes (CDC, 2014). This condition is known as prediabetes and becomes more prevalent with age, affecting about 51% of the adults aged 65 years or older (CDC, 2014). Those with prediabetes are at an increased risk of developing type 2 diabetes, demonstrating the potential rise in the number of Americans diagnosed with diabetes in the future.

The continual rise in the prevalence along with an elevated incidence of diabetes corresponds with an increasing economic burden due to the chronic nature of this disease and the devastating occurrence of complications (Ng, Lee, Toh, & Ko, 2014). To further exacerbate this economic burden, it is common for individuals with diabetes to suffer from additional comorbid conditions (Lkhagva, Kuwabara, Matsuda, Gao, & Babazono, 2012; Struijs, Baan, Schellevis, Westert, & Bos, 2006). Health care utilization and hospitalization increases for each additional complication and/or comorbid condition present among individuals with diabetes with the greatest utilization incurred among those who also have cardiovascular disease or renal complications (American Diabetes Association [ADA], 2013; Carral et al., 2003; Struijs et al., 2006).

The use of emergency department (ED) services has increased within the U.S., along with the number of diabetes-related ED visits (CDC, 2015; National Center for Health Statistics, 2015). This is problematic due to the ED not being a sufficient source of care for treating diabetes or preventing the complications and comorbid conditions associated with more severe cases. Long-term disease management becomes critical given the complexity and chronic nature of diabetes, which warrants a more continuous form of care with consistent follow-ups in a primary care setting to help delay the progression of disease severity and deterioration in health (ADA, 2015; Wagner et al., 2001).

Routine use of the ED for medical care may be an indicator of reduced access to primary care, demonstrating that location of residence matters. This is evidenced by how certain geographic areas display disproportionately higher rates as a result of variations in racial composition and housing ownership characteristics within a neighborhood (Cunningham, 2006; Li, Grabowski, McCarthy, & Kehen, 2003). Other significant neighborhood-level determinants of elevated ED rates include a greater proportion of female residents and renter-occupied/vacant housing units (Li et al., 2003).

The literature examining the neighborhood-level determinants of ED utilization among individuals with diabetes also demonstrates a disproportionate number of ED visits occurring in neighborhoods with a higher proportion of minority, less educated, and poorer residents (Livingood et al., 2010; Steiner, Barrett, & Hunter, 2010). However, the literature is often limited to only a few demographic and socioeconomic characteristics including those listed above as well as the rural/urban designation of a neighborhood (Livingood et al., 2010; Steiner et al., 2010). Thus, the influence of a neighborhood's characteristics on ED utilization among individuals with diabetes deserves further investigation in order to identify other determinants related to the environment. To expand upon the literature, this study examined the association between several neighborhood characteristics and ED utilization in South Carolina, which has the fourth highest diabetes prevalence in the nation (South Carolina [SC] Division of Diabetes, Heart Disease, Obesity, and School Health, 2014).

MATERIALS AND METHODS

Study Design

This study was a secondary data analysis of ED discharge data from January 1, 2013 to December 31, 2013 in South Carolina using Geographic Information Systems (GIS) to geocode patient data. Data were derived from several different sources including ED discharge data for diabetes-related visits, American Community Survey (ACS) data, U.S. Postal Service ZIP Code coordinates, and boundaries for the 5-digit ZIP Code Tabulation Areas (ZCTAs) from the 2010 U.S. Census. The study area included the entire state of South Carolina and data were compiled to the ZCTA level. The University of

South Carolina Institutional Review Board determined this study protocol to be exempt from IRB review because it met the criteria for not human research.

Data Sources

<u>Diabetes-related ED discharge data</u>

The ED discharge data were obtained from data reported by civilian hospitals in South Carolina to the South Carolina Revenue and Fiscal Affairs Office (RFA – formerly called the Office of Research and Statistics). Hospitals are mandated to report all ED visits using a standardized format that includes patient and provider information, primary and secondary diagnoses, and residence of patients. The primary and all 14 secondary diagnoses for each ED visit have been standardized by the RFA using the International Classification of Diseases Version 9 (ICD-9) codes.

Eligible diabetes-related ED visits for the year 2013 were identified by using the ICD-9 code 250.xx (inclusive) as either the primary cause or as a contributing condition for ED utilization. A total of 174,991 diabetes-related visits to the ED were identified for 2013. All pregnancy-related ED visits with an ICD-9 code of 648.0 or 648.8 were excluded in order to prevent the inclusion of visits pertaining to gestational diabetes or complications encountered by expecting mothers with pre-existing diabetes (n=617). Additionally, the major/minor diagnostic category that each patient's primary ED diagnosis was classified as were used to exclude visits that were associated with pregnancy, complications of pregnancy, or routine infant/child checkups (n=200). Any visit with missing demographic information such as sex, race, or ID number were excluded as well (n=68), resulting in a total of 174,106 visits being considered for this analysis.

In 2009, the RFA began assigning a unique identifier to each patient treated in the ED or who were hospitalized. This unique ID was used to extract each patient's first visit that occurred between January 1, 2013 and December 31, 2013, and was used to calculate the total number of diabetes-related ED visits that occurred in this time period per patient. In 2013, there were a total of 96,360 unique patient records extracted. Each patient record contained several demographic and spatial characteristics including age, sex, race, mailing address ZIP code, and county of residence.

U.S. Postal Service ZIP Code Coordinates

ZIP code centroids for the year 2013 were obtained from the South Carolina Department of Health Structured Query Language (SQL) Server Enterprise Geodatabase (SC Department of Health and Environmental Control [SC DHEC], 2013). This database contained only residential ZIP codes making the centroids for P.O. boxes unavailable. However, it has been found that inaccurately geocoding a patient to the ZIP code centroid of a P.O. Box is likely to lead to misclassification of neighborhood-level attributes (Hurley, Saunders, Nivas, Hertz, & Reynolds, 2003), and therefore, any patient record with a ZIP code designated as a P.O. Box was excluded from this analysis (n=1,493). Additionally, any patient record with a missing ZIP code, out-of-state ZIP code, or inappropriate ZIP code digit entry was also excluded (n=3,351).

Population Size and Sociodemographic Data for ZCTAs

The geographical boundaries for each 5-digit ZCTA were obtained from the 2010 U.S. Census and imported as a shapefile from the TIGER/Line products website (United States [U.S.] Census Bureau, 2010a). The ZCTA polygons were joined to the ZCTA level attribute dataset containing 2013 ACS five-year estimates of population size, demographic (i.e. distribution of age, sex, and race), and socioeconomic characteristics (i.e. health insurance, median income, employment, educational attainment, poverty, occupancy characteristics of housing units, and household and family structure) (U.S. Census Bureau, 2013). The percentage of households designated as living in a rural/urban area was obtained from the 2010 U.S. Census (U.S. Census Bureau, 2010b). The population size for each ZCTA was used to account for differences in population density by dividing the number of ED patients with diabetes for a given ZCTA by the total number of individuals residing within the respective ZCTA. The average number of ED visits per patient with diabetes was calculated by dividing the total number of diabetes-related ED visits that occurred in 2013 by the total number of patients with diabetes residing within their respective ZCTA.

Study Protocol

ArcGIS software, Version 10.2.2 for Windows (Environmental Systems Research Institute, Redlands, CA) was used to geocode patient data using ZIP codes based on the mailing address of each patient. ZIP code boundaries tend to change due to the periodic updates that may realign boundaries or discontinue certain delivery areas, thus making it difficult to map their boundaries accurately (Grubesic & Matisziw, 2006; Wey, Griesse, Kightlinger, & Wimberly, 2009). Therefore, each ZIP code was spatially joined to a 5-digit ZCTA from the 2010 U.S. Census. This process associated each ZIP code centroid with their respective ZCTA based on whether the latitude and longitude coordinates fell within the boundaries of the assigned ZCTA. In South Carolina, there were a total of 323 residential ZIP codes in 2013 along with 423 ZCTAs from the 2010 U.S. Census. ZCTAs with a frequency less than 10 patients were excluded because of small sample size (n=73), resulting in 350 ZCTAs and a final sample of 91,461 unique patient records that were used in this analysis.

Data Analysis

Chloropleth maps were created using ArcGIS to provide a visual representation of the geographic variation in the density of ED patients with diabetes per 100 persons across South Carolina as well as for the average number of ED visits per patient with diabetes. Spatial analysis tools within ArcGIS were used including Moran's I coefficient with row standardization to test for spatial autocorrelation and Getis-Ord Gi* to test for spatial clustering of high values (hot spots) and low values (cold spots) across the entire study area (Moran, 1950; Getis & Ord, 1992). Data analysis was performed at the ZCTA level and spatial relationships between neighboring ZCTAs was conceptualized for both spatial tools using the Fixed Distance Band option, a recommended strategy for use with polygons of varying size, with the neighborhood search threshold set at the default.

SAS software, Version 9.3 for Windows (SAS Institute, Cary, NC) was used to analyze the data at the ZCTA level. The demographic characteristics of the ZCTAs were generated and reported as means and standard deviations for continuous variables, and frequencies and proportions for categorical variables. The outcome variables included the standardized density of ED patients with diabetes per 100 persons and the average number of ED visits per patient with diabetes. The explanatory variables included several neighborhood-level characteristics which were categorized into quartiles with the exception of the percent of households designated as rural, which was categorized into tertiles because of the large number of ZCTAs that were completely rural. Due to the skewed distribution of both outcome variables, spearman rank correlations were calculated to determine if there was an association between the outcome variables and each of the neighborhood-level characteristics as continuous variables. Additional comparisons by neighborhood-level characteristics were performed using the nonparametric Kruskal-Wallis test to determine if there was a significant difference between the tertiles/quartiles. Following the identification of significant hot and cold spots, descriptive statistics were generated to compare the neighborhood-level characteristics between significant hot/cold spots with non-clustered areas for both outcome variables. Statistical significance was set at $p \leq 0.05$.

RESULTS

The 91,461 patients with diabetes included in this analysis accumulated over 166,905 ED visits during 2013. The average number of ED visits per patient with diabetes was 1.74 visits (range = 1.15 to 3.38 visits) with 35.27% of these patients visiting the ED at least twice and another 5.51% visiting five or more times within a 12-month period. Additionally, the average age of these patients was 58.64 years and 58.92% were females, 50.62% were white, and 51.39% were Medicare beneficiaries.

Figure 1 portrays the spatial distribution of patients with diabetes who utilized the ED in 2013. The test of global spatial autocorrelation was statistically significant indicating that there was spatial clustering of ED patients with diabetes per 100 persons (Moran's I = 0.19; p-value < 0.001). Figure 2 depicts the spatial distribution of the average number of ED visits per patient with diabetes and there was also evidence of spatial clustering at the ZCTA-level (Moran's I = 0.30; p-value < 0.001).

Examining the average neighborhood (i.e. ZCTA) in South Carolina demonstrated that nearly half of the residents were female (51.03%), predominantly white (67.97%), with a median age of 40.50 years (Table 4.1). The majority of the housing units were owner-occupied (59.75%) with only 18.35% vacant. The median income per household was $41,035 and only 20.20% of residents lived below the federal poverty level. Of the total number of households in each ZCTA, 68.33% were classified as family households predominantly made up of married-couple families (47.77%) and single-female householders (15.4%).

The population standardized density of ED patients with diabetes was significantly correlated with several neighborhood-level characteristics (Table 4.2). A significant inverse correlation was observed between the density of ED patients with diabetes and the percent of owner-occupied housing units in a neighborhood. Specifically, ZCTAs with more than 67.09% owner-occupied housing units had a lower number of ED patients with diabetes per 100 persons in comparison to ZCTAs with less than 54.20% owner-occupied housing units. Those areas with a median income greater than $47,202 had about half the density of ED patients with diabetes than areas with a median income less than $32,445. The density of ED patients decreased from 3.63 to 2.06 per 100 persons as the proportion of residents with at least a high school education increased from 75.69% to greater than 86.50%. Furthermore, ZCTAs with less than 41.23% of family households with a married couple had a higher density of ED patients with diabetes as compared to areas with greater than 54.78% of family households, which was also demonstrated by the significant inverse correlation between these two variables.

The average number of visits per patient with diabetes over a 12-month period was also significantly correlated with several neighborhood-level characteristics (Table 4.2). Average number of ED visits among patients with diabetes increased as the proportion of African American residents increased in the neighborhood from less than 14.8% to greater than 46.4%. Similarly, there was a significant positive correlation between the number of ED visits per patient with diabetes and the percent of Medicaid beneficiaries, percent living below federal poverty level, and percent of family households with a single-female householder. Utilization of the ED among patients with diabetes was lower in neighborhoods with a higher proportion of owner-occupied housing units and a greater number of residents with at least a high school education. The average number of ED visit decreased from 1.78 to 1.65 visits per patient with diabetes as the median income increased from $32,444.99 to greater than $47,202. The neighborhood characteristics that were not significantly correlated with average number of ED visit per patient with diabetes included the proportion of female residents, percent of family households, percent of family households with a single-male householder, and percent of households designated with a rural residence.

Comparisons made between hot and cold spots with non-significant areas demonstrated disparities in terms of neighborhood-level characteristics (Table 4.3 and Figure 3). Of the total 350 ZCTAs included in this analysis, 16 (4.57%) were identified as being statistically significant hot spots for the density of ED patients with diabetes and were predominantly found in the Upstate and Low Country regions. The significant cold spots were located geographically near major metropolitan areas of bordering states possibly demonstrating the effect of border crossing for health care. ZCTAs identified as hot spots for ED patients with diabetes were more likely to occur in areas with a higher proportion of African Americans, Medicaid/Medicare beneficiaries, unemployed, and less educated residents in comparison to individuals residing in non-cluster areas.

Furthermore, residents residing in hot spots were older with a median age of 43.16 years. Also, the percent of individuals living below the federal poverty level was higher in hot spot areas as well as the proportion of households designated as living in a rural area compared to the residents residing in non-significant clusters.

The hot spots identified in Figure 4 portrayed a slightly different picture when examining the areas with clustering of high average number of ED visits per patient with diabetes. A total of 61 (17.43%) hot spots and 41 (11.71%) cold spots were identified out of the 350 ZCTAs used in this analysis. The two largest hot spots were located primarily in the Upstate and Midlands region of the state, while the largest cold spot was located in the Low Country region. The residents of areas classified as hot spots were more likely to be younger with a median age of 38.00 years as compared to the non-cluster ZCTAs (Table 4.4). Additionally, residents of significant hot spots were more educated, of non-family households, and had a higher median income. The percent of housing units classified as being vacant was lower as well as the percent of family households and married couple households as compared to residents living in non-clustered areas. ZCTAs identified as hot spots of average number of ED visits per patient with diabetes were less likely to be rural areas.

DISCUSSION

The facilitated use of GIS in this study provides evidence of small-area variations and spatial clustering in both the standardized density of ED patients with diabetes and the average number of ED visits per patient with diabetes in South Carolina. The geographic location of these spatial clusters along with their corresponding demographic and socioeconomic characteristics demonstrates that a gradient in ED utilization exists among patients with diabetes. Areas of elevated spatial density of ED patients with diabetes were concentrated to neighborhoods of low socioeconomic status as well as those with a higher proportion of residents who are older, of minority race, and with a rural residency. Similar neighborhood-level characteristics were also related to the average number of ED visits per patient with diabetes with the exception of age and rural designation.

Since most health care utilization studies focus primarily on visit rates, differences in primary outcomes make comparison between the findings of this study and the literature difficult in terms of ED patient density. However, the clustering of ED patients with diabetes to certain geographic areas within South Carolina have similar characteristics as identified in one study examining the spatial clustering of diagnosed diabetes prevalence at the county level in the United States (Shrestha, 2012). High-prevalence counties surrounded by neighboring counties with similarly high prevalence had a higher proportion of non-Hispanic African Americans, uninsured residents, and poverty levels in comparison to non-cluster counties (Shrestha, 2012). Furthermore, South Carolina had a plurality of these high-high spatial clusters of diabetes prevalence (Shrestha, 2012) indicating that the concentration of individuals with diabetes to certain geographic areas is likely to coincide with an elevated density of ED patients with diabetes. Livingood et al. (2010) noted this observation in their analysis of diabetes prevalence and rates of hospitalization and ED use among geographically defined health zones in Duval County, Florida. The urban core of the county displayed a disproportionately higher prevalence of diabetes as well as an elevated rate of diabetes-related ED visits (Livingood et al., 2010).

The literature has identified additional characteristics associated with small-area variations in diabetes prevalence including education levels, income, percentage of single-parent households, unemployment rates, crime level, and number of vacant/placarded dwellings (Green, Hoppa, Young, & Blanchard, 2003). This study also demonstrates that geographic areas displaying disproportionately higher density of ED patients with diabetes were associated with racial composition and percent of residents living below the federal poverty level. Additional neighborhood-level socioeconomic characteristics found in this study include unemployment status, median income, educational attainment, and housing ownership. Furthermore, characteristics of the household family structure were significantly related to the density of ED patients with diabetes. Neighborhoods with a lower proportion of family households with a married couple or a greater proportion of family households with a single-female householder were more likely to have a higher concentration of ED patients with diabetes per 100 persons. Moreover, this study reveals that neighborhoods identified as significant hot spots for the density of ED patients with diabetes also appear to be a function of racial composition, older age, unemployment, low educational attainment, Medicaid/Medicare insurance status, and rural designation. These enabling characteristics demonstrate the vulnerability of these neighborhoods possibly due to limited resources available for residents to receive appropriate health care in order to treat their diabetes (Andersen, Yu, Wyn, Davidson, Brown, & Teleki, 2002; Livingood et al., 2010), indicating that the location of residence is an important determinant of health care accessibility.

When the focus shifts to the average number of ED visits per patient with diabetes, the neighborhood-level characteristics were similar to those identified previously for areas with clustering of ED patients with diabetes but with some noted differences. The average number of ED visits per patient with diabetes was consistently observed in neighborhoods with a higher minority population and a lower socioeconomic status. The literature has also identified educational attainment, median income, insurance coverage, citizenship, percent living at or below the federal poverty level, and percent of owner-occupied housing units of a neighborhood as significant predisposing environmental factors associated with increased ED utilization in the general population (Cunningham, 2006; Li et al., 2003; Livingood et al., 2010). This study further establishes some of these same factors to be associated with increased ED use among patients with diabetes in addition to the proportion of Medicaid beneficiaries, unemployed residents, family households with a married couple, and family households with a single-female householder within a neighborhood. Additionally, the frequency of ED utilization among patients with diabetes decreased in neighborhoods as the proportion of adults over the age of 65 years increased. This was further demonstrated in the hot/cold spot analysis where significant hot spots of elevated ED use were more likely to occur in areas with a higher proportion of younger residents.

However, noted differences were observed between the characteristics of these clustered high use areas in comparison to the overall population characteristics of the entire state. Specifically, neighborhoods identified as hot spots had a higher proportion of residents with more education, non-family households, and higher median income in comparison to the non-cluster areas. A national study across multiple U.S. neighborhoods likewise demonstrated variations in neighborhood-level characteristics between study areas of elevated ED use (Cunningham, 2006). The two cities with the highest ED utilization rates in this particular study were also observed to have the lowest proportion of uninsured residents (Cunningham, 2006), thus demonstrating that there is a possibility of variations in ED utilization even with or without the presence of significant neighborhood-level determinants found in the literature to be associated with elevated ED use.

The two large hot spot clusters of elevated ED visits among patients with diabetes were geographically located in the Midlands and Upstate regions of the state which are close to major metropolitan areas (Greenville and Columbia) that have several hospitals and EDs within the vicinity. The literature demonstrates that elevated ED utilization is significantly associated with the average number of EDs per 10,000 persons in the population (Cunningham, 2006), which may partly explain the clustering of high values to those two geographic areas in South Carolina. Furthermore, residing within close proximity of a hospital impacts ED utilization through the concept of distance decay (Chen, Cheng, Bennett, & Hibbert, 2015; Li et al., 2003; Lowe et al., 2009; Mathison et al., 2013; Parker & Campbell, 1998); however, there is some inconsistency noted in the literature (Cunningham, 2006). In South Carolina, another study demonstrated that the distance to the ED is a significant predictor of non-urgent ED use among privately insured or self-pay patients (Chen et al., 2015). This finding may explain the spatial clustering of elevated ED visits among patients with diabetes to more urban neighborhoods due to the possible convenience of an ED within close proximity of their residence.

There are several limitations that should be considered. The accuracy of the data obtained for each ED visit is affected by the correctness of the information collected and entered within each patient record and therefore, errors in data entry is possible. For the purposes of this analysis, all ICD-9 codes for each of the ED visits were assumed to have been coded accurately since they were used to extract diabetes-related visits. Another limitation is the possibility of misclassifying patients as not having diabetes, if patient medical history was not accurately obtained by medical staff or if laboratory bloodwork was not performed for diagnostic purposes. Furthermore, the accuracy of the fifth digit of ICD-9 codes is low which limits the ability to distinguish between type 1 and type 2 diabetes, and therefore, this study could not assess the differences between the types. Lastly, since aggregated data was used to measure the neighborhood-level characteristics for each ZCTA, there is the limitation of ecological fallacy that prevents the ability to draw conclusions at the individual level. Nevertheless, this study has identified meaningful neighborhood-level determinants associated with ED utilization among patients with diabetes.

This study reveals that the density of ED patients with diabetes as well as the average number of ED visits per patient with diabetes vary significantly within neighborhood-level characteristics and are spatially clustered to certain geographic locations within South Carolina. These findings highlight important neighborhood-level determinants that may predispose certain patients with diabetes to rely on the ED for routine medical care. Unfortunately, the ED is not a sufficient health care setting for treating diabetes or preventing its complications and comorbid conditions because of the necessity for continuous medical care. A neighborhood-level approach may be necessary for identifying spatial clusters of elevated ED use among individuals with diabetes because of how exposure to adverse neighborhood-level characteristics may increase dependency upon the ED for routine care. An effort to reduce this reliance on the ED is essential for effectively treating this chronic condition and therefore, necessitates the need to target neighborhoods with high ED utilization by addressing the impeding issues associated with limited accessibility to primary care providers and economic resources available to residents.

Table 4.1 Neighborhood-level characteristics of the ZIP code tabulation areas (ZCTA) in South Carolina (n=350)

	Mean (SD)	Range
Total population	12,671.60 (12,604.90)	213 – 66,204
Age		
Median age (years)	40.50 (6.24)	20.70 – 66.20
% 65 years and older	15.53 (5.77)	0 – 56.00
% female residents	51.03 (4.18)	18.17 – 63.97
% African American residents	32.30 (21.93)	0 – 92.97
Number of housing units	5,838.05 (5,742.00)	97 – 28,158
% owner-occupied housing units	59.75 (11.88)	0 – 86.29
% renter-occupied housing units	21.89 (10.02)	2.55 – 58.44
% vacant housing units	18.35 (11.21)	0 – 73.19
Insurance status		
% uninsured	17.39 (5.66)	1.70 – 40.70
% Medicaid beneficiaries	20.08 (8.25)	0 – 43.60
% Medicare beneficiaries	19.25 (6.07)	0 – 57.60

% private insurance	58.92 (11.40)	30.60 – 93.40
% below federal poverty level	20.20 (8.82)	0 – 59.20
Median income ($)	41,034.99 (12,653.83)	12,115 – 94,463
% unemployed	12.81 (5.08)	0 – 36.30
Education		
% with at least a high school education	81.13 (7.64)	55.10 – 99.90
% with at least a Bachelor's degree	19.17 (12.41)	0 – 73.60
Number of households	4,838.58 (4,826.88)	86 – 23,755
% family households	68.33 (8.76)	5.81 – 93.89
% of family households with a married couple	47.77 (10.23)	5.81 – 78.17
% of family households with single-male householder	4.78 (2.71)	0 – 17.65
% of family households with single-female householder	15.78 (6.38)	0 – 37.20

% non-family households	31.67 (8.76)	6.11 – 94.19
% of non-family households with householder living alone	27.49 (7.38)	6.11 – 82.56
% rural residence	63.95 (39.19)	0 - 100

Note: SD, standard deviation

Table 4.2 Density of ED patients with diabetes per 100 persons and the average number of ED visits per patient with diabetes by Neighborhood-level characteristics

	Density of ED patients with diabetes per 100 persons			Average # of ED visits		
	Mean	Mean Wilcoxon Score	Spearman's ρ	Mean	Mean Wilcoxon Score	Spearman's ρ
% 65 years and older						
< 12.49	2.49	140.80		1.76	184.42	
12.50 – 14.54	2.81	183.39		1.77	190.90	
14.55 – 17.39	2.58	188.15		1.77	185.66	
17.40 +	3.14	188.44*	0.16†	1.65	141.09*	-0.14†
% female residents						
< 49.30	3.20	170.67		1.70	161.57	
49.31 – 51.59	2.40	160.60		1.76	186.50	
51.60 – 53.10	2.42	169.64		1.71	166.91	
53.11 +	3.01	200.97	0.11	1.78	186.76	0.05

% African American residents						
< 14.88	2.38	126.77		1.69	158.09	
14.89 – 28.64	2.22	146.26		1.70	161.06	
28.65 – 46.39	2.74	187.86		1.76	187.52	
46.40 +	3.68	240.69*	0.43†	1.79	195.28*	0.14†
% owner-occupied housing units						
< 54.20	3.22	193.63		1.78	191.71	
54.21 – 61.53	2.97	192.64		1.78	189.46	
61.54 – 67.08	2.62	171.56		1.72	168.94	
67.09 +	2.21	144.33*	-0.18†	1.68	152.00*	-0.14†
% uninsured						
< 13.69	2.77	145.26		1.68	149.26	
13.70 – 17.19	2.94	185.09		1.80	195.5	
17.20 – 20.39	2.52	178.99		1.75	183.35	
20.40 +	2.80	192.49*	0.17†	1.73	173.95*	0.08

% Medicaid beneficiaries						
< 14.09	2.15	110.42		1.67	146.64	
14.10 – 19.79	2.52	162.34		1.73	177.51	
19.80 – 26.29	2.79	195.99		1.74	177.88	
26.30 +	3.55	231.77*	0.46[†]	1.81	199.32*	0.21[†]
% below federal poverty level						
< 13.49	2.28	116.56		1.62	130.94	
13.50 – 19.79	2.46	168.17		1.74	174.92	
19.80 – 25.59	2.82	196.18		1.78	197.97	
25.60 +	3.44	219.48*	0.37[†]	1.81	197.40*	0.24[†]
Median income, $						
< 32,444.99	3.53	240.61		1.78	190.72	
32,445.00 – 39,073.49	3.21	196.82		1.77	188.20	
39,073.50 – 47,201.99	2.59	168.30		1.75	183.74	
47,202.00 +	1.70	96.93*	-0.53[†]	1.65	139.60*	-0.17[†]

% unemployed						
< 9.29	2.45	131.34		1.66	147.30	
9.30 – 12.29	2.16	147.34		1.73	175.08	
12.30 – 15.79	2.82	199.32		1.82	199.76	
15.80 +	3.57	222.15*	0.37[†]	1.74	179.17*	0.14[†]
% with at least a high school education						
< 75.69	3.63	231.76		1.78	188.02	
75.70 – 80.74	2.90	199.40		1.77	189.16	
80.75 – 86.49	2.46	173.97		1.76	189.36	
86.50 +	2.06	98.60*	-0.48[†]	1.64	135.72*	-0.20[†]
% family households						
< 64.55	3.01	174.03		1.77	184.48	
64.56 – 69.51	2.78	194.66		1.73	173.63	
69.52 – 74.07	2.64	176.13		1.74	177.36	
74.08 +	2.60	157.17	-0.09	1.71	166.65	-0.08

% of family households with a married couple						
< 41.23	3.36	212.98		1.81	199.56	
41.24 – 48.30	2.62	189.89		1.78	195.35	
48.31 – 54.77	2.40	155.60		1.67	153.23	
54.78 +	2.64	143.74*	-0.29[†]	1.69	153.88*	-0.22[†]
% of family households with single-male householder						
< 3.03	3.11	174.98		1.69	153.68	
3.04 – 4.41	2.40	160.13		1.76	179.48	
4.42 – 6.19	2.40	171.30		1.77	189.35	
6.20 +	3.11	195.55	0.07	1.74	179.40	0.08
% of family households with single-female householder						
< 11.64	2.29	122.84		1.68	149.22	
11.65 – 15.53	2.63	158.74		1.71	163.61	
15.54 – 19.84	2.83	183.56		1.76	184.91	
19.85 +	3.28	236.35*	0.39[†]	1.81	204.07*	0.20[†]

% of households designated as living in rural area						
< 44.09	2.10	123.97		1.75	180.50	
44.10 – 99.99	2.55	182.78		1.77	191.51	
100.00	3.34	209.62*	0.37†	1.72	163.88	-0.09

*Kruskal-Wallis test: significance at $p \leq 0.05$ rejects the null hypothesis that there is no difference between the tertiles/quartiles.
† Significant at $p \leq 0.05$

Table 4.3 Neighborhood-level characteristics of ZCTAs by spatial clustering type for the density of ED patients with diabetes

	Hot Spots (n=16)*	Cold Spots (n=14)[†]	Non-Cluster ZCTAs (n=320)
Age			
Median age	43.16 (4.54)	39.30 (5.14)	40.42 (6.33)
% 65 years and older	17.56 (7.55)	14.62 (4.84)	15.47 (5.71)
% female residents	49.83 (3.27)	51.32 (1.56)	51.07 (4.29)
% African American residents	43.49 (31.13)	20.00 (14.60)	32.27 (21.42)
Number of housing units	3,732.69 (4,438.29)	9,626.93 (7,643.05)	5,777.55 (5,648.75)
% owner-occupied housing units	58.18 (10.95)	61.56 (13.39)	59.75 (11.88)
% renter-occupied housing units	17.09 (8.55)	24.09 (9.93)	22.04 (10.05)
% vacant housing units	24.72 (14.90)	14.35 (13.40)	18.21 (10.82)
Insurance status			
% uninsured	16.24 (5.06)	14.18 (5.60)	17.59 (5.65)
% Medicaid beneficiaries	24.00 (8.40)	16.41 (8.64)	20.05 (8.17)
% Medicare beneficiaries	21.78 (7.94)	16.74 (4.68)	19.23 (5.98)

% private insurance	54.65 (8.91)	66.19 (14.84)	58.82 (11.23)
% below federal poverty level	22.93 (8.22)	18.49 (9.35)	20.14 (8.83)
Median income ($)	40,708.25 (12,218.67)	52,434.00 (22,589.30)	40,552.62 (11,892.06)
% unemployed	14.63 (5.93)	11.41 (3.52)	12.78 (5.08)
Education			
% with at least a high school education	77.68 (6.73)	85.09 (11.30)	81.13 (7.43)
% with at least a Bachelor's degree	15.49 (12.45)	28.49 (19.06)	18.95 (11.91)
Number of households	2,944.94 (3,537.62)	8,526.36 (7,077.41)	4,771.92 (4,698.83)
% family households	69.09 (5.91)	68.68 (6.20)	68.28 (8.98)
% of family households with a married couple	48.94 (12.21)	50.98 (9.75)	47.57 (10.16)
% of family households with single-male householder	5.49 (3.52)	4.39 (1.61)	4.76 (2.71)
% of family households with single-female householder	14.66 (6.70)	13.32 (5.74)	15.95 (6.38)

% non-family households	30.91 (5.91)	31.32 (6.20)	31.72 (8.98)
% of non-family households with householder living alone	27.14 (5.31)	27.41 (5.98)	27.51 (7.53)
% rural residence	84.26 (22.88)	20.95 (19.83)	64.82 (39.20)

Note: Data shown as means and standard deviations.
*Hot spot represents a ZCTA with a high value surrounded by neighboring ZCTAs with like high values.
† Cold spot represents a ZCTA with a low value surrounded by neighboring ZCTAs with like low values.

Table 4.4 Neighborhood-level characteristics of ZCTAs by spatial clustering type for the average number of ED visits per patient with diabetes

	Hot Spots (n=61)*	Cold Spots (n=41)†	Non-Cluster ZCTAs (n=248)
Age			
Median age	38.00 (6.52)	41.76 (8.69)	40.90 (5.52)
% 65 years and older	14.11 (5.36)	16.28 (7.68)	15.75 (5.47)
% female residents	51.38 (5.96)	50.56 (3.85)	51.01 (3.68)
% African American residents	31.47 (22.43)	32.81 (22.04)	32.41 (21.87)
Number of housing units	7,538.34 (5,654.07)	8,058.71 (7,841.18)	5,052.71 (5,168.33)
% owner-occupied housing units	57.08 (14.11)	54.11 (17.71)	61.34 (9.51)
% renter-occupied housing units	26.65 (12.12)	23.34 (13.00)	20.49 (8.41)
% vacant housing units	16.27 (10.92)	22.55 (18.26)	18.17 (9.52)
Insurance status			
% uninsured	16.74 (5.75)	19.10 (5.58)	17.27 (5.62)
% Medicaid beneficiaries	18.60 (7.97)	18.55 (7.75)	20.70 (8.35)
% Medicare beneficiaries	17.23 (5.53)	19.58 (7.32)	19.69 (5.89)

% private insurance	61.81 (10.74)	58.47 (11.97)	58.29 (11.39)
% below federal poverty level	18.03 (8.58)	20.14 (9.56)	20.75 (8.71)
Median income ($)	42,972.38 (10,798.26)	40,256.93 (11,664.89)	40,687.08 (13,218.64)
% unemployed	11.82 (4.41)	12.52 (4.89)	13.11 (5.24)
Education			
% with at least a high school education	83.39 (7.65)	82.11 (8.60)	80.41 (7.37)
% with at least a Bachelor's degree	24.06 (12.66)	19.86 (11.88)	17.85 (12.17)
Number of households	6,555.15 (5,059.40)	5,894.66 (5,865.81)	4,241.76 (4,456.41)
% family households	64.72 (13.15)	66.75 (9.61)	69.48 (6.82)
% of family households with a married couple	45.46 (12.63)	46.76 (10.68)	48.50 (9.42)
% of family households with single-male householder	4.12 (2.35)	4.87 (2.89)	4.93 (2.75)
% of family households with single-female householder	15.13 (6.66)	15.13 (5.69)	16.05 (6.42)

% non-family households	35.28 (13.15)	31.25 (9.61)	30.52 (6.82)
% of non-family households with householder living alone	29.68 (10.45)	28.71 (8.02)	26.75 (6.16)
% rural residence	44.56 (41.95)	52.10 (45.90)	70.68 (35.21)

Note: Data shown as means and standard deviations.
*Hot spot represents a ZCTA with a high value surrounded by neighboring ZCTAs with like high values.
† Cold spot represents a ZCTA with a low value surrounded by neighboring ZCTAs with like low values.

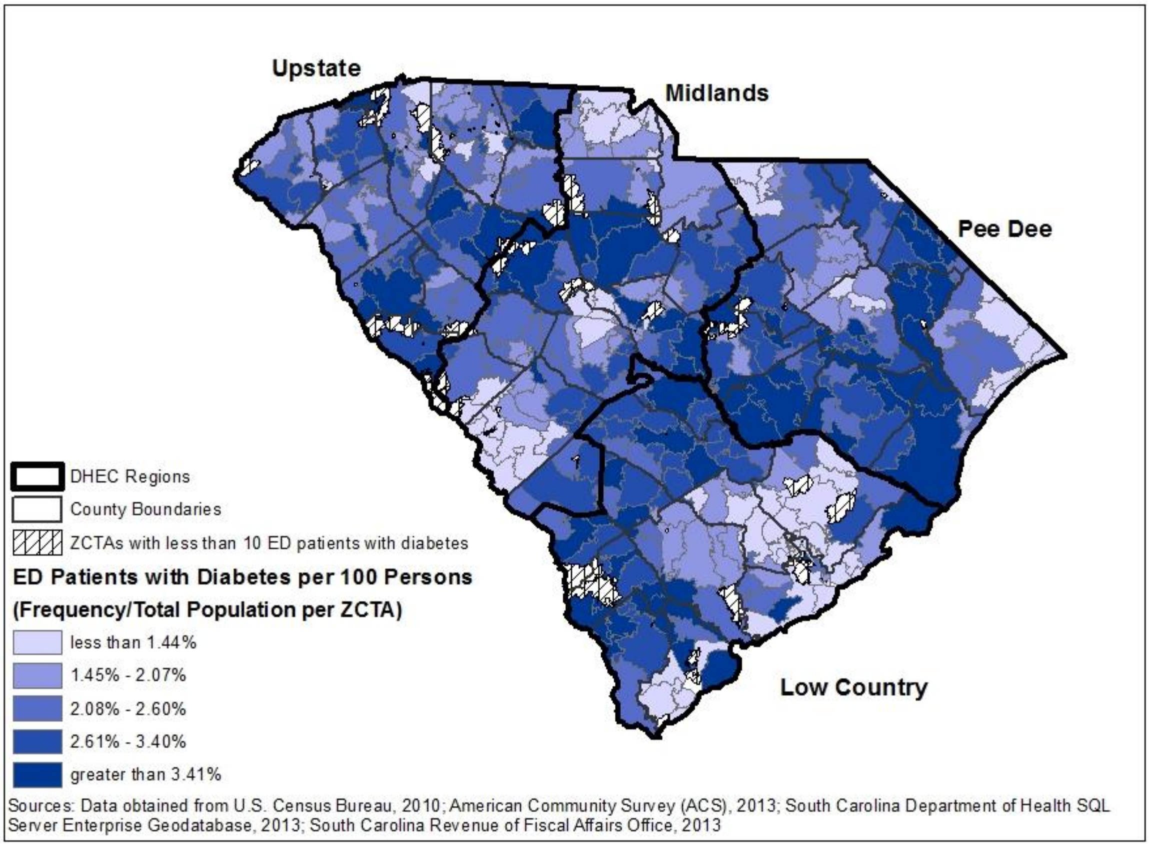

Figure 4.1 Spatial distribution of ED patients with diabetes as a percent of the total population residing within each ZCTA in South Carolina, 2013

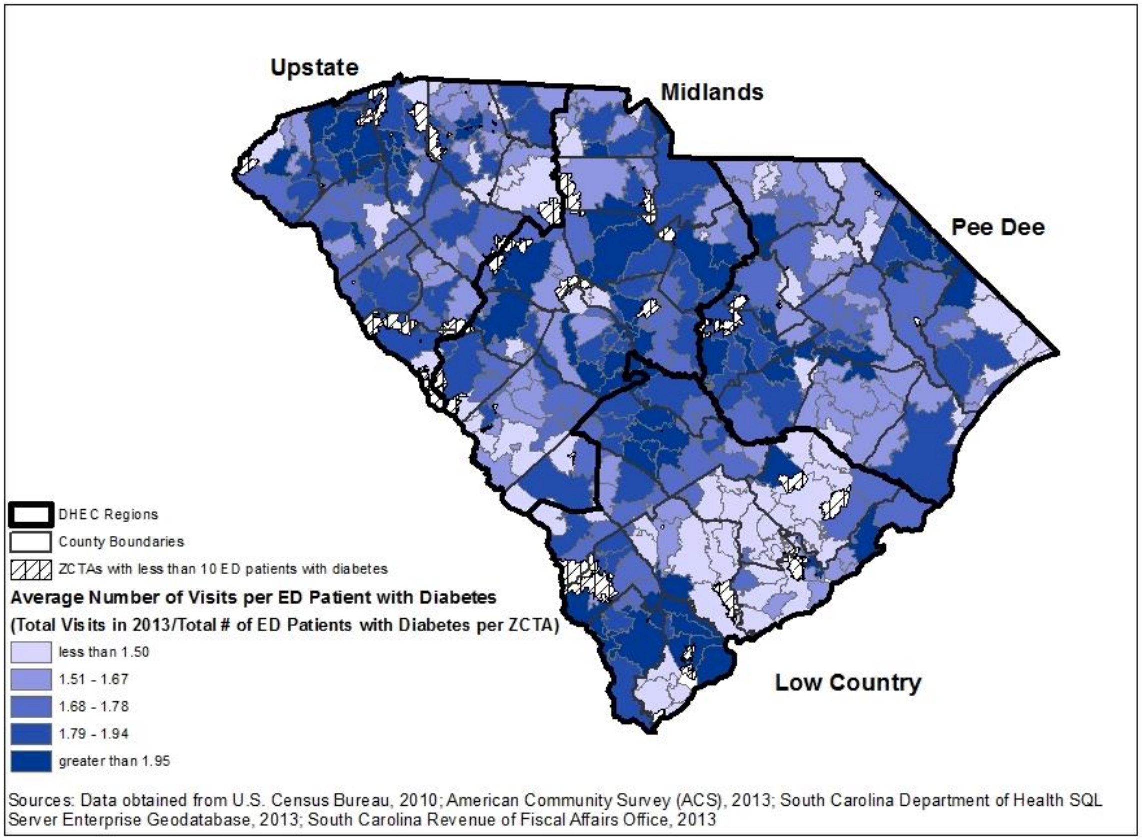

Figure 4.2 Spatial distribution of average number of visits per ED patient with diabetes within each ZCTA in South Carolina, 2013

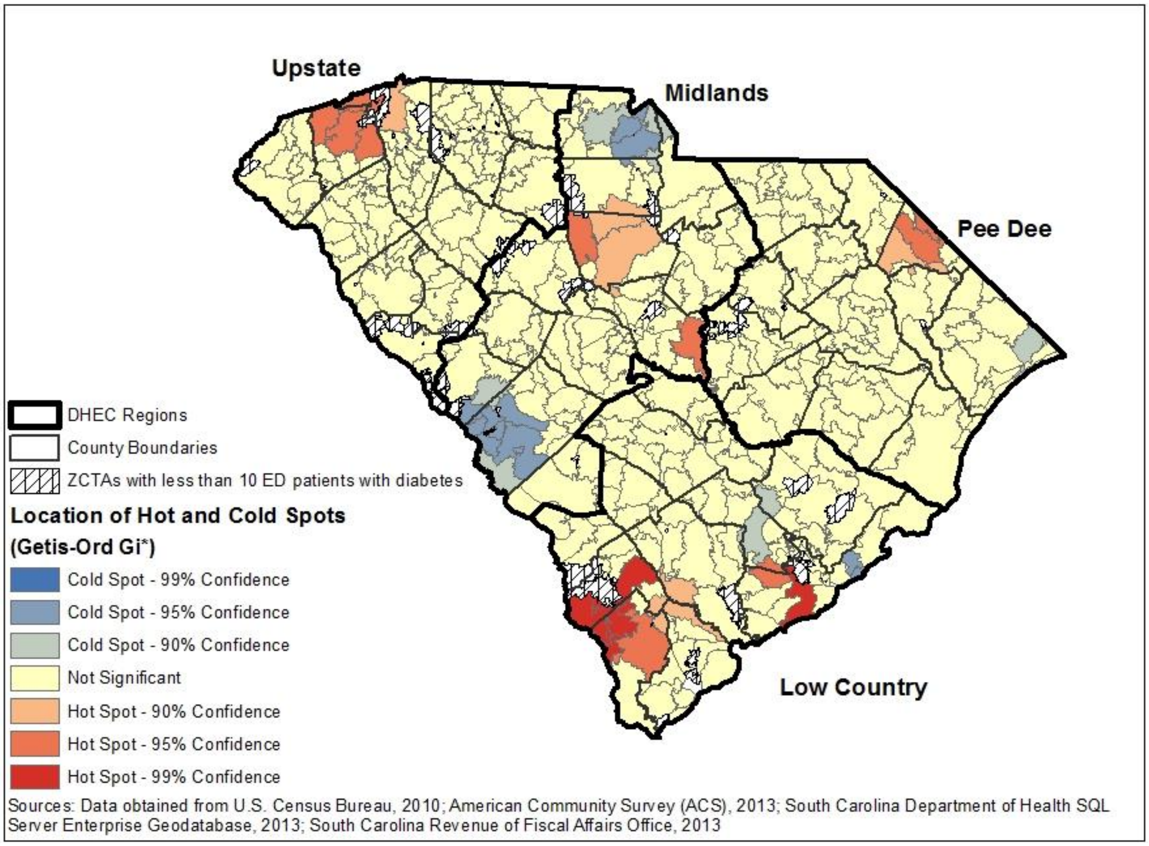

Figure 4.3 Location of significant hot and cold spots for the density of ED patients with diabetes per 100 persons by ZCTA in South Carolina, 2013

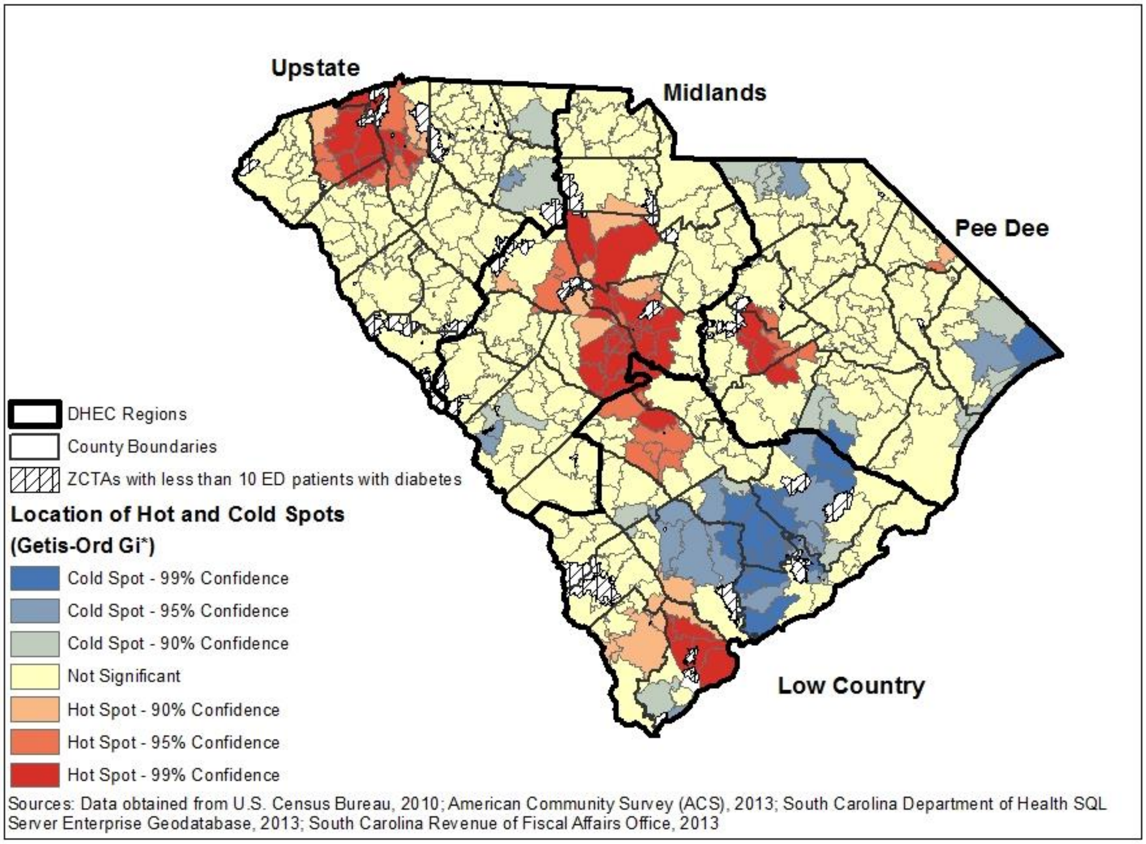

Figure 4.4 Location of significant hot and cold spots for average number of visits per ED patient with diabetes per ZCTA in South Carolina, 2013

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CHAPTER 5

MANUSCRIPT 2- ASSOCIATION OF INDIVIDUAL- AND NEIGHBORHOOD-LEVEL CHARACTERISTICS WITH FREQUENT EMERGENCY DEPARTMENT USE AMONG PATIENTS WITH DIABETES: A MULTILEVEL ANALYSIS[2]

[2] Breneman, CB & Eberth, JM. To be submitted to the Journal of Epidemiology and Community Health.

ABSTRACT

Objective

This study explored the effects of both individual- and neighborhood-level characteristics associated with frequent emergency department (ED) use among patients with diabetes in South Carolina.

Methods

Frequent ED use among patients with diabetes was defined as three or more visits to the ED in a twelve month period during 2013 in South Carolina. Individual-level outcomes and measures were obtained from ED discharge data. Neighborhood boundaries were defined by 2010 U.S. Census ZIP Code Tabulation Areas and data on each neighborhood's demographic, socioeconomic status, and rural/urban status were obtained from the 2013 American Community Survey and the 2006 Rural-Urban Community Area Codes. The relationships between individual- and neighborhood-level variables with frequent ED use were assessed using two-level hierarchal logistic regression models with random neighborhood intercepts.

Results

After controlling for neighborhood-level variables and random neighborhood effects, individual-level measures of age, sex, race, and primary source of payment were all significantly associated with frequent ED use among patients with diabetes. A significant interaction between individual-level measures of race and sex was also found (p-value < 0.01). At the neighborhood-level, measures of material deprivation and rural/urban status of a neighborhood had neighborhood demonstrated little to no effect on the propensity toward using the ED.

Conclusion

After accounting for neighborhood-level characteristics and random neighborhood effects, patients with diabetes who were younger, African American females, or Medicaid/Medicaid beneficiaries were more likely to be frequent ED users. Whereas, neighborhood-level measures of material deprivation and rural/urban status did not account for much of the unexplained neighborhood heterogeneity indicating that other neighborhood-level variables should be identified.

INTRODUCTION

The prevalence and incidence of diabetes are disproportionately higher among specific populations and geographic areas, potentially demonstrating the influence of individual-level and neighborhood-level characteristics. The greatest burden of this disease occurs among individuals of low socioeconomic status (SES), minority race/ethnicity, and/or rural residency (Brancati, Whelton, Kuller, & Klag, 1996; Krishna, Gillespie, & McBride, 2010; Robbins, Vaccarino, Zhang, & Kasl, 2005). Furthermore, vulnerable neighborhoods with a higher proportion of minority, lower education and income levels, greater number of single-parent households and vacant/placarded dwellings, and higher unemployment and crime rates are more likely to have a higher prevalence of diabetes (Green, Hoppa, Young, & Blanchard, 2003). Like characteristics were also found among individuals who displayed higher rates of emergency department (ED) utilization indicating the possibility that similar individual- and neighborhood-level characteristics of frequent ED use may be prominent determinants among individuals with diabetes.

Disparities in ED use among patients with diabetes exist in the literature. At the individual level, there is a disproportionately higher tendency to use the ED for care among patients with diabetes who are younger, African American, less educated, and of female gender (Bazargan, Johnson, & Stein, 2003). Similarly, among older Medicare beneficiaries with diabetes, African Americans, less educated, and female patients were more likely to use the ED in comparison to their respective counterparts (Chin, Zhang, & Merrell, 1998).

In addition, the literature pertaining to neighborhood-level characteristics demonstrates elevated diabetes-related ED visits within low income or rural neighborhoods compared to wealthier or urban neighborhoods (Steiner, Barrett, & Hunter, 2010). One particular study observed variations in diabetes-related ED utilization rates between six health zones in Duval County, Florida (Livingood et al., 2010). A disproportionately higher rate of diabetes-related ED visits was demonstrated in the urban core of this county, which also had a higher proportion of African Americans, less educated, and poorer residents as compared to the other five health zones (Livingood et al., 2010). The vulnerability of these subgroups demonstrates that the existence of certain individual- and neighborhood-level characteristics may potentially lead an individual with diabetes to depend on the ED for routine care.

The ED is not an optimal setting for long-term disease management due to the lack of continuity of care received that subsequently may lead to hospitalization and/or readmission (Jiang, Friedman, Stryer, & Andrews, 2003). Unfortunately, the age-adjusted ED visit rates for diabetes have increased from 41.0 to 47.4 per 1,000 adults between 2006 and 2009 (Centers for Disease Control and Prevention [CDC], 2015). The literature investigating ED use among patients with diabetes has often examined the association between utilization rates with individual- (Bazargan et al., 2003; Capp, Rooks, Wiler, Zane, & Ginde, 2013; Chin et al., 1998; McCusker, Cardin, Bellavance, & Belzile, 2000) and neighborhood-level characteristics separately (Kruzikas, Barrett, Coffey, & Andrews, 2004; Livingood et al., 2010). Given the significant differences in ED utilization among patients with diabetes with individual- and neighborhood-level characteristics, further investigation of this relationship using multilevel modeling is warranted. This study examined the effects of both individual- and neighborhood-level characteristics associated with frequent ED use among patients with diabetes using ED discharge data.

METHODS

Study Setting

This study combined multiple data sources in order to provide individual-level outcomes that are nested within neighborhoods, so that the multilevel associations could be examined. Frequent ED use among patients with diabetes was defined as three or more visits to the ED in a twelve month period from January 1, 2013 to December 31, 2013. The setting for this study was the state of South Carolina and the sources of data included ED discharge data for 2013, data from the 2013 American Community Survey (ACS), U.S. Postal Service ZIP Code centroids, 2006 Rural-Urban Community Area Codes (RUCAs), and the 2010 U.S. Census ZIP Code Tabulation Areas (ZCTAs). The protocol of this study was exempted from IRB review by the University of South Carolina Institutional Review Board because of the use of de-identified secondary data.

Individual-Level Data and Variables

The ED discharge data from 2013 for all civilian hospitals in South Carolina were obtained from the South Carolina Revenue and Fiscal Affairs Office (RFA – formerly called the Office of Research and Statistics). To identify all eligible ED visits with a diabetes diagnosis, the primary or one of the 14 secondary diagnoses had to contain an International Classification of Diseases Version 9 (ICD-9) code of 250.xx (inclusive). There were a total of 174,991 diabetes-related ED visits identified for the year of 2013. Of these 174,991 diabetes-related ED visits, the following were excluded: ED visits with an ICD-9 code of 648.0 or 648.8 which represent pregnancies with gestational diabetes or pre-existing diabetes (n=617), ED visits containing a major/minor diagnostic category classifying the primary diagnosis as being associated with pregnancy, complications of pregnancy, or routine infant/child checkups (n=200), and any ED visit missing important demographic information (n=68). These exclusion criteria resulted in a total of 174,106 diabetes-related ED visits being considered for further analysis.

Each ED visit contained a unique identifier that the RFA began assigning in 2009 to patients receiving care in the ED or who were hospitalized. This identifier was used to extract individual patient records by selecting the first ED visit that occurred within the timeframe of the study for each patient, resulting in a total of 96,360 unique patient records for 2013. Also, the unique identifier was used to calculate the total number of diabetes-related ED visits for each patient which was then dichotomized as non-frequent ED use (one or two ED visits) or frequent ED use (more than three ED visits) and thus served as the individual-level outcome measure for this study. Individual-level predictors were likewise obtained from each patient record and included demographic information on age, sex, race (i.e. White, African American, or other), and primary source of payment (i.e. self/indigent, Medicaid, Medicare, private insurance, or other).

Neighborhood-Level Data and Variables

Each patient record contained a ZIP code based on the patient's mailing address, which was not released to the study team. Since ZIP codes tend to change periodically due to frequent updates, boundary reassignments, or discontinuation (Grubesic & Matisziw, 2006; Wey, Griesse, Kightlinger, & Wimberly, 2009), neighborhood boundaries were defined geographically using 2010 U.S. Census 5-digit ZCTA polygons (n=423) obtained from the TIGER/Line product website (U.S. Census Bureau, 2010). The Townsend Material Deprivation Index was used as a measure of neighborhood SES and was calculated for each ZCTA using the 2013 ACS five-year estimates for the following variables: percent of unemployed residents over the age of 16 years, percent of households with more than one person per room, percent of households with no vehicle, and percent of rented-occupied housing units (Townsend, Phillimore, & Beattie, 1988; United States Census Bureau, 2013). A high score for the Townsend Deprivation Index was indicative of greater material deprivation. Each ZCTA was also designated as rural or urban based on the RUCA approximation assigned to the ZIP code(s) located within the geographic boundaries of the ZCTA polygon (WWAMI Rural Health Research Center, 2007).

The centroids of ZIP codes were used to geocode each patient record to a ZCTA using ArcGIS software, Version 10.2.2 for Windows (Environmental Systems Research Institute, Redlands, CA). The centroid coordinates for all residential ZIP codes (n=323) in South Carolina for 2013 were obtained from the South Carolina Department of Health

Structured Query Language (SQL) Server Enterprise Geodatabase (South Carolina Department of Health and Environmental Control [SC DHEC], 2013). Any patient with a missing, out-of-state, non-residential, or P.O. Box ZIP code were excluded from this analysis (n=4,844). Additionally, any ZCTA with a frequency less than 10 patients with diabetes were excluded due to small sample size (n=73 ZCTAs), which resulted in a final sample of 91,461 patients (individual-level) with diabetes clustered within 350 ZCTAs (neighborhood-level).

Data Analyses

All statistical analyses were performed in SAS, Version 9.3 (SAS Institute Inc., Cary, NC). Means and standard deviations for continuous variables and frequencies and proportions for categorical variables were calculated for each predictor variable at the individual- and neighborhood-levels. Due to the nesting of patients with diabetes within ZCTAs, a two-level, random-intercept hierarchical logistic regression model was used to examine the relationship between frequent ED use and the predictor variables. The PROC GLIMMIX syntax in SAS was used to estimate values for all variables in the models based on the LAPLACE estimation method (Raudenbush, Yang, & Yosef, 2000). ZCTAs were included as a random effect, and the individual- and neighborhood-level independent variables were included as fixed-effects. The bivariate relationships between categorical and continuous predictors at both levels with frequent ED use were evaluated using two-level hierarchical logistic regression models controlling for random neighborhood effect.

Five nested hierarchical logistic regression models were specified and the results were reported as odds ratios (ORs) and 95% confidence intervals (CIs) for within cluster comparisons at the individual-level and as 80% interval odds ratios (IOR-80) for quantifying the effect of neighborhood-level variables. The first model represented the unconditional means model comprising of just a neighborhood-level random intercept and no predictors. Model 2 was an extension of the first model and included all individual-level predictors as fixed effects: age (centered on the grand mean), sex, race (i.e. White, African American, or other), and primary source of payment (i.e. self/indigent, Medicaid, Medicare, private insurance, or other). Preliminary review of the data revealed a possible interaction between race and sex which led to the inclusion of this cross-product interaction as a fixed effect in Model 3. Models 4 and 5 build upon the previous individual-level models by introducing neighborhood-level predictors sequentially. Neighborhood SES as determined by Townsend Material Deprivation Index (grand mean centered) was added in Model 4 followed by the rural/urban designation of the neighborhood as fixed effects in Model 5. The median odds ratio (MOR) was estimated for each model in order to quantify the amount of variation between ZCTAs (Larsen, Petersen, Budtz-Jorgensen, & Endahl, 2000; Merlo et al., 2006).

RESULTS

Of the 91,461 patients with diabetes, 8,292 (9.07%) visited the ED three or more times during the year of 2013 in South Carolina. Patient characteristics of frequent and non-frequent ED users and bivariate associations with frequency of ED use are presented in Table 5.1. All individual-level predictors were found to be significantly associated with frequent ED use among patients with diabetes. Furthermore, the IOR-80 for both neighborhood-level variables contained the value one indicating that the SES and rural/urban designation of a neighborhood did not account for much of the neighborhood heterogeneity in the propensity toward frequent ED use among patients with diabetes.

Table 5.2 shows the results of several multiple hierarchical logistic regression models examining the association between individual- and neighborhood-level predictors with frequent ED use. For the unconditional model (Model 1), there was a significant amount of neighborhood variability in the odds of frequent ED use among patients with diabetes ($p < 0.001$). For two patients with identical characteristics randomly selected from different neighborhoods, the MOR between a patient with diabetes of higher propensity for frequent ED use with a patient of lower propensity was estimated to be 1.42.

The inclusion of individual-level predictors as fixed effects in Model 2 resulted in the between-neighborhood variance to decrease by 5.11%, but this remained statistically significant yielding an MOR similar in Model 1. All of the individual-level effects on the odds of frequent ED use were statistically significant. The magnitude and significance of age on the odds of frequent ED use did not change between Tables 5.1 and 5.2. Female patients with diabetes had a greater odds of being frequent ED users in comparison to male patients with diabetes independent of sex, race, primary source of payment, and neighborhood (OR = 1.18; 95% CI = 1.12 – 1.24). African American patients with diabetes had a higher odds of being frequent ED users in comparison to White patients with diabetes (OR = 1.26; 95% CI = 1.20 – 1.33); whereas, those categorized in the other racial class had a 38% lower odds of being frequent ED users (95% = 0.52 – 0.74) after adjusting for other patient characteristics and neighborhood. Those whose primary source of payment was Medicaid or Medicare were significantly more likely to be frequent users compared to those who self-paid or were indigent (OR = 1.43; 95% CI = 1.33 – 1.54; OR = 1.20; 95% CI = 1.12 – 1.28, respectively). Whereas, those who used private insurance or another source of payment were less likely to be frequent ED users among patients with diabetes as compared to the referent group after accounting for age, sex, race, and neighborhood (OR = 0.44; 95% CI =0.40 – 0.47; OR = 0.60; 95% CI = 0.46 – 0.78, respectively).

Model 3 shows a significant interaction between race and sex ($p < 0.01$), which did not change the between-neighborhood variance from the previous model or the MOR. The significance and magnitude of the relationships between age and primary source of payment with frequency of ED use did not change between Models 2 and 3. After controlling for a patient's age and primary source of payment for ED visit, White females and African American males and females all had greater odds of being frequent ED users by a factor of 1.30 (95% CI = 1.21 – 1.39), 1.40 (95% CI = 1.30 – 1.53), and 1.53 (95% CI = 1.42 – 1.64) compared to White males, respectively. Whereas, both male and female patients with diabetes classified in the other category for race had a lower odds of being frequent ED users in relation to White males (OR = 0.69; 95% CI = 0.52 – 0.90; OR = 0.76; 95% CI = 0.60 – 0.95, respectively).

The remaining two models in Table 5.2 introduced neighborhood-level variables. The IOR-80 for material deprivation was 0.55 to 1.96 for Model 4, which contained the value one implying that neighborhood material deprivation did not account for a substantial amount of the neighborhood heterogeneity in the propensity toward frequent ED use among patients with diabetes. The significance and magnitude of the relationship between the individual-level variables and frequency of ED use remained the same for age and primary source of payment; whereas, slight attenuation was observed for the racial/sex groups. The between-neighborhood variation remained significant; however, it decreased by approximately 10.2% based on the predictors included in Model 4 in comparison the unconditional means model. Also, the inclusion of neighborhood SES as a covariate attenuated the unexplained heterogeneity in frequent ED use between neighborhoods slightly (MOR = 1.40). Further adjustment of the rural/urban designation of a neighborhood did not impact the between-neighborhood variation which remained statistically significant ($p < 0.01$) (Model 5). Also, the associations remained nearly the same for all of the individual-level variables and the Townsend Material Deprivation Index. The IOR-80 for rural/urban status was 0.56 to 1.99, which contained the value one indicating that the neighborhood rural/urban status did not account for a substantial amount of the heterogeneity between neighborhoods in the propensity toward frequent ED use in this population.

DISCUSSION

Patients with diabetes are a medically vulnerable population because of the chronic nature of their condition and the occurrence of complications and comorbid conditions (Broyles, McAuley, & Baird-Holmes, 1999). Consequently, each additional complication and/or comorbid condition leads to greater health resource use among patients with diabetes which often includes the ED (American Diabetes Association [ADA], 2013; Carral et al., 2003; Struijs, Baan, Schellevis, Westert, & Bos, 2006). The propensity toward frequent ED use among patients with diabetes was demonstrated in this study to be a function of individual-level measures of age, sex, race, and primary source of payment. At the neighborhood-level, measures of material deprivation and rural/urban status of a neighborhood had little to no effect on the propensity toward using the ED.

This study demonstrated that patients with diabetes who are younger, African American, Medicare/Medicaid beneficiaries, and/or of female gender had greater odds of being frequent ED users compared to their respective counterparts. These results are consistent with another study examining ED utilization among minority under-served patients with diabetes (Bazargan et al., 2003). Additionally, among older Medicare beneficiaries with diabetes, African Americans, less educated, and female patients were more likely to use the ED in comparison to their respective counterparts (Chin et al., 1998).

Another important finding of this study is the significant interaction between individual-level measures of race and sex, which demonstrated that African American female patients with diabetes had a significantly higher odds of being frequent ED users in comparison to all other racial/sex groups (results not shown). Similarly, in a stratified analysis by race and sex, older African American women with diabetes on Medicare had significantly higher rates of ED utilization compared to White women (Chin et al., 1998). The similarities in these findings are somewhat limited by the noted differences in statistical analyses employed to investigate this association. The literature mostly accounted for individual-level predictors of ED utilization via single-level statistical models; whereas, this present study expands upon these findings by also accounting for the contextual impact of the neighborhood on frequent ED utilization via multilevel modeling.

At the neighborhood-level, the MOR for the final model provided evidence of variation between neighborhoods in the propensity toward frequent ED use among patients with diabetes even with the inclusion of individual- and neighborhood-level characteristics. However, the IOR-80 for neighborhood material deprivation and rural/urban designation were wide and contained the value one indicating that a large amount of the neighborhood heterogeneity was not accounted for by these neighborhood characteristics. This indicates that there may be other neighborhood-level factors in addition to individual-level characteristics that may predispose certain patients with diabetes to use the ED more than others.

Due to the complexity and chronic nature of diabetes, a more continuous form of care over the life course is necessary; indicating that an individual’s ability to manage their disease long term may be impacted by health behaviors and/or exposure to adverse neighborhood-level characteristics during childhood. Brown and colleagues (2004) demonstrated this conceptually by examining how socioeconomic position (SEP) over the course of one’s life may impact behaviors and health outcomes, such as ED utilization among individuals with diabetes. The SES at the individual-, household-, and neighborhood-levels as well as the accumulated effects of SES over time are encompassed within SEP, thus demonstrating its multidimensionality (Brown et al., 2004).

Brown and colleagues (2004) further indicated that the health infrastructure of a neighborhood may potentially impact diabetes self-management. This concept was demonstrated in a single-level analysis that used neighborhood SES as a proxy measure for individual-level SES and found that individuals residing in low-income neighborhoods had a higher rate of ED visits for hypoglycemia/hyperglycemia as well as a greater tendency of recurrent ED utilization (Booth & Hux, 2003). Another study using a mixed effects analysis observed a significant association between neighborhood SES and hemoglobin A1c levels, indicating that poor disease management was more likely among individuals who lived in low income neighborhoods (Geraghty, Balsbaugh, Nuovo, & Tandon, 2010). Also, living within close proximity to a patient's primary care provider resulted in greater adherence to treatment plans for insulin administration (Geraghty et al., 2010). These findings persisted even after adjusting for individual- and provider-level characteristics, thus demonstrating that neighborhood SES may exert an independent effect on diabetes management. The accumulation of these environmental exposures over time may lead to future diabetes-related complications and subsequent ED utilization as a result of poor disease management (Brown et al., 2004), implying that the behavioral process driving some individuals with diabetes to utilize the ED for routine care is complex and involves measuring characteristics at the individual-, household-, and neighborhood-level.

This study has several limitations that need to be considered. First, the individual-level characteristics of patients with diabetes were obtained from their first visit to the ED during the study period, and therefore, are cross-sectional. However, this would only affect age and primary source of payment. Additionally, measures of individual- and household-level SES are not available in ED discharge data, which limits the use of neighborhood-level SES as a proxy measure of individual-level SES. Third, there is the possibility that the Townsend Material Deprivation Index may have underestimated the effect of neighborhood context in this study since it is a composite score of characteristics which may or may not directly impact the behavioral process leading to ED utilization. Fourth, the timing and duration of exposure to neighborhood-level characteristics were not measured and therefore, could potentially underestimate the effect of neighborhood-level SES on ED utilization in this population. Lastly, there are several other neighborhood-level characteristics that were not accounted for in this study including proximity to ED, density of primary care providers, and cultural norms that may influence health behaviors and/or health service use.

In summary, the use of multilevel modeling allowed for the clustering of individuals within the same neighborhood to be accounted for which strengthens the findings of this study. The odds of elevated frequent ED use was demonstrated among patients with diabetes who are younger, African American female, and/or primarily use Medicare/Medicaid insurance for medical costs which persisted even after adjusting for neighborhood-level characteristics and random neighborhood effects. The low amount of variability accounted for by the neighborhood-level predictors included in this study indicates the need for additional research within this population especially given the heterogeneity between neighborhoods. Area of residence as well as household characteristics may predispose certain individuals with diabetes to use the ED more frequently than others based on their individual characteristics. Future research should explore the complementary effects of individual-, household-, and neighborhood-level characteristics on the behavior process leading to ED use as well as the accumulation of exposures over the life course among individuals with diabetes.

Table 5.1 Individual- and neighborhood-level characteristics of sample population by frequency of ED use (n=91,461) and ZIP code tabulation areas (ZCTA) (n=350)

	Non-frequent (n=83,169)	**Frequent (n=8,292)**	**OR (95% CI)**
Outcome			
Frequency of ED visits, mean (SD)	1.37 (0.63)	6.39 (4.72)	-
Individual-level variables			
Age (years), mean (SD)	59.22 (16.28)	52.84 (16.08)	0.98
			(0.98–0.98)
Sex, % (n)			
Male	58.41 (34,591)	64.05 (5,311)	1.00
Female	41.59 (48,578)	35.95 (2,981)	1.25
			(1.19–1.31)
Race/Ethnicity, % (n)			
White	51.39 (42,737)	42.98 (3,564)	1.00
African American	45.91 (38,179)	55.23 (4,580)	1.45

			(1.38–1.53)
Other	2.71 (2,253)	1.78 (148)	0.77
			(0.65–0.91)
Primary source of payment, % (n)			
Self/Indigent	16.78 (13,957)	22.13 (1,835)	1.00
Medicaid	9.02 (7,503)	19.39 (1,608)	1.64
			(1.53–1.77)
Medicare	51.85 (43,121)	46.76 (3,877)	0.70
			(0.66–0.74)
Private insurance	21.16 (17,597)	10.94 (907)	0.40
			(0.37–0.44)
Other	1.19 (991)	0.78 (65)	0.55
			(0.42–0.71)
Neighborhood-level variables	-	**Mean (SD)**	**IOR-80**
Townsend Material Deprivation Index	-	-0.20 (1.94)	(0.58–1.99)

% renter-occupied housing units	-	26.72 (12.18)	-
% of unemployed residents over 16 years	-	12.81 (5.08)	-
% of households with more than 1 person per room	-	1.92 (1.59)	-
% of households with no car	-	7.55 (4.83)	-
Neighborhood Rural/urban status (rural vs. urban)	-	-	(0.57–2.17)
Urban, % (n)	-	55.14 (193)	-
Rural, % (n)	-	44.86 (157)	-

Note: Frequent ED use was defined as 3 or more ED visits within a 12-month period. CI, confidence interval; IOR, interval odds ratio; OR, odds ratio; SD, standard deviation.

Table 5.2 Odds Ratios (95% Confidence Intervals) for associations between individual- and neighborhood-level variables with frequent ED use among patients with diabetes

	Model 1	Model 2	Model 3	Model 4	Model 5
Individual-level Fixed Effects			*Odds ratio*		
Age	-	0.97	0.97	0.97	0.97
		(0.97–0.98)	(0.97–0.98)	(0.97–0.98)	(0.97–0.98)
Sex					
Male	-	1.00	-	-	-
Female	-	1.18	-	-	-
		(1.12–1.24)			
Race					
White	-	1.00	-	-	-
African American	-	1.26	-	-	-
		(1.20–1.33)			
Other	-	0.62	-	-	-
		(0.52–0.74)			

Primary source of payment					
Self/Indigent	-	1.00	1.00	1.00	1.00
Medicaid	-	1.43	1.43	1.43	1.43
		(1.33–1.54)	(1.33–1.55)	(1.33–1.54)	(1.32–1.54)
Medicare	-	1.20	1.20	1.20	1.20
		(1.12–1.28)	(1.12–1.29)	(1.12–1.29)	(1.12–1.28)
Private insurance	-	0.44	0.44	0.44	0.44
		(0.40–0.47)	(0.40–0.47)	(0.40–0.48)	(0.40–0.48)
Other	-	0.60	0.60	0.60	0.60
		(0.46–0.78)	(0.46–0.78)	(0.46–0.78)	(0.46–0.78)
Race*sex					
White Male	-	-	1.00	1.00	1.00
White Female	-	-	1.30	1.29	1.29
			(1.21–1.39)	(1.21–1.39)	(1.21–1.39)
African American Male	-	-	1.40	1.40	1.40

			(1.30–1.53)	(1.29–1.51)	(1.29–1.52)
African American Female	-	-	1.53	1.51	1.51
			(1.42–1.64)	(1.41–1.62)	(1.41–1.63)
Other Male	-	-	0.69	0.68	0.68
			(0.52–0.90)	(0.52–0.89)	(0.52–0.89)
Other Female	-	-	0.76	0.75	0.75
			(0.60–0.95)	(0.60–0.95)	(0.60–0.95)
Neighborhood-level Fixed Effects			*Interval odds ratio*		
Townsend Material Deprivation Index	-	-	-	(0.55–1.96)	(0.55–1.96)
Neighborhood Rural/urban Status (rural vs. urban)	-	-	-	-	(0.56–1.99)
Neighborhood Random Effects					
Intercept variance component, (SE)	0.137* (0.017)	0.130* (0.017)	0.130* (0.017)	0.123* (0.016)	0.124* (0.016)
Median odds ratio	1.42	1.41	1.41	1.40	1.40

Note: SE = standard error.
* Significant at $p < 0.05$

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CHAPTER 6

CONCLUSION

This thesis reveals that the density of ED patients with diabetes as well as the average number of ED visits per patient with diabetes vary significantly within neighborhood-level characteristics (e.g. % African American residents, % Medicaid beneficiaries, % below federal poverty level, and median income) and are spatially clustered to certain geographic locations (e.g. Upstate region) within South Carolina. These findings highlight important neighborhood-level determinants that may predispose certain patients with diabetes to rely on the ED for routine medical care. However, after accounting for individual-level characteristics via random-intercept multilevel modeling, neighborhood-level measures of material deprivation and rural/urban status had little to no effect on the neighborhood heterogeneity in frequent ED use among patients with diabetes. Whereas, individual-level measures of age, sex, race, and primary source of payment remained significant predictors of frequent ED use.

These findings identify significant individual-level predictors associated with frequent ED use, which represent the predisposing and enabling characteristics specified within the Andersen's Behavioral Model. However, measures of need-for-care characteristics and SES at the individual level were not available in this dataset and should be accounted for. Additionally, the low amount of variability accounted for by the neighborhood-level predictors included in this study indicates the need for additional research within this population especially given the heterogeneity between neighborhoods. A more comprehensive description of the surrounding neighborhood should include additional variables that describe a neighborhood's demand for care, support for services, health structure, and dynamics of the health market (Andersen et al., 2002).

To fully understand the behavior process leading to increased ED utilization among individuals with diabetes, all levels of the population and environmental domains of the Andersen's Behavioral Model may need to be accounted for. Additionally, the spatial clustering of elevated average ED visits per patient with diabetes to certain geographic locations in South Carolina indicates a spatial component to this relationship. Future research should spatially explore the complementary effects of individual-, household-, and neighborhood-level characteristics on the behavior process leading to the use of the ED as well as the accumulation of exposures over the life course, in order to effectively reduce the number of individuals with diabetes who rely on the ED.

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