

**AN ANALYSIS OF EMERGENCY DEPARTMENT UTILIZATION  
AMONG PREGNANT MEDICAID BENEFICIARIES**

by

Mary Culnane

A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Urban Affairs and Public Policy

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Mary Culnane

Approved: \_\_\_\_\_  
Sarah Bruch, Ph.D.  
Chair of the Department of Urban Affairs and Public Policy

Approved: \_\_\_\_\_  
Maria P. Aristigueta, D.P.A.  
Dean, Joseph R. Biden, Jr. School of Public Policy and Administration

Approved: \_\_\_\_\_  
Louis F. Rossi, Ph.D.  
Vice Provost for Graduate and Professional Education and  
Dean of the Graduate College

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed:

---

Paul Solano, Ph.D.  
Professor in charge of dissertation

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed:

---

John McNutt, Ph.D.  
Member of dissertation committee

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed:

---

Mia Papas, Ph.D.  
Member of dissertation committee

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed:

---

Allison Karpyn, Ph.D.  
Member of dissertation committee

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## **ABSTRACT**

Nationwide the total number of Emergency Department (ED) visits by Medicaid recipients increased from approximately 128 million visits in 2009 to 143 million visits in 2018. While EDs are a key component of the United States Health Care system, policy makers are concerned about the high costs and overcrowding associated with ED use, particularly among patients who have access to other sources of care. It is acknowledged that ED utilization varies widely across populations and individuals and without information on unique patient populations, policy and clinical interventions remain uninformed and inadequate. Relative to other populations, few studies have investigated use of the ED by pregnant women during the prenatal period. The purpose of this study was to identify factors associated with ED use that can be used to predict the number of ED visits among pregnant Medicaid recipients. Factors that influence the number of ED visits were explored using a Negative Binomial regression model to predict the number of ED visits among pregnant women during the prenatal period. The study utilized Medicaid data collected in the state of Delaware over a 5-year period (fiscal years 2007-2012). Findings revealed that of the 23,824 cases in the study, 40.5% (9,649/23,824) utilized the ED at least once during their prenatal period. Among those who visited the ED, the total number of visits made over the course of the prenatal period was 22,883; of those, 54.4% were made by women who visited the ED less than four times. The remaining 45.6% were made by women who made four or more visits. The Negative Binomial regression model supports the following results. Several sociodemographic characteristics were associated with ED

visits. Results from the model revealed that younger pregnant women utilized the ED more than older women in the study cohort. Black pregnant women visited the ED more than women of other races/ethnic groups. Being a pregnant woman with a disability was associated with more ED visits when compared with pregnant women without disabilities. Several clinical factors were also associated with ED visits. Pregnant women with higher health risks, including maternal comorbidities, visited the ED more than pregnant women with no or lower health risks. Pregnant women who were admitted to inpatient care within 24 hours of an ED visit utilized the ED more than those who were not admitted or never visited the ED. Pregnant women with maternal related conditions at the time of the ED visit utilized the ED more than those who visited for other health issues or never visited the ED. Last, pregnant women with longer duration of Medicaid coverage during the prenatal period utilized the ED more than women with shorter duration of Medicaid coverage. This dissertation contributes to the sparse literature on ED utilization by pregnant women enrolled in Medicaid by exploring and identifying factors associated with ED utilization using a methodology appropriate for count data. Such population-specific studies are needed to inform coherent, efficient, and effective programs and policies.

## Chapter 1

### INTRODUCTION AND RESEARCH QUESTIONS

#### 1.1 Introduction

Prenatal primary care is thought of as patient-centered, coordinated, efficient, cost-effective, and associated with establishing care continuity between pregnant women and their prenatal primary caregivers. In the United States, Medicaid has a long-standing public health mandate to provide access to prenatal care. In 2020, Medicaid financed 42% of all births nationwide (*Births Financed by Medicaid*.2021). Overall program goals are aimed at maintaining maternal health, promoting health improvements, reducing disparities, and improving maternal and infant outcomes (Institute of Medicine, 2001; Sultz & Younge, 2011). Prenatal care models, financed by Medicaid, encourage access to services and continuity of care during the prenatal period by linking pregnant women to primary care and obstetrical care providers. However, pregnant women often seek unscheduled care in settings other than their primary prenatal care provider setting, including the Emergency Department (ED). Using the ED during pregnancy may interfere with the overall prenatal care program goals and policy experts and clinicians question whether ED use contributes to observed poor pregnancy outcomes among racial/ethnic minorities and women who are in the lower socioeconomic bands. Thus, identifying and understanding ED utilization that can be used to predict the number of ED visits among Medicaid beneficiaries during pregnancy is a key step in informing, developing, and driving

evidence-based practice and of particular interest to policy makers, clinicians, and public health experts for several reasons.

First, it is not clear if pregnant women use the ED as substitute for prenatal care in a primary care setting, or if the ED serves as a complement to care needs. In order to understand this, policy and program managers first need an accurate profile of ED utilization including level of use, conditions and reasons for presentation to the ED, and ED visit urgency measures.

Second, by consulting the ED, rather than the prenatal primary care provider, it is possible that care becomes fragmented and is associated with sub-optimal maternal and infant outcomes. While some ED visits may be true emergencies, other visits may not be; in cases where there is not a true emergency, it is likely that women would be better off if they consulted their prenatal primary care provider or obstetrician in order to maintain continuity (Matteson et al., 2008).

Third, from a cost perspective, ED visits are three to six times more expensive than visits to other ambulatory care settings (Caldwell et al., 2013; Mehrotra et al., 2008; Thygeson et al., 2008) with higher costs often attributed to the increased use of sophisticated diagnostic technology for ED workups. In many cases, a visit to the ED results in testing and treatments that have been labeled as unnecessary (Bamezai et al., 2005; Durand et al., 2012; Guttman et al., 2001; Uscher-Pines et al., 2013). When comparing costs of care across comparable conditions, receiving care at an ED can be anywhere from 4 to 12 times higher than receiving care at a physician's office or urgent care center (*The High Cost of Avoidable Hospital Emergency Department Visits*. 2019; Caldwell et al., 2013). For pregnant women in particular, visits to the ED can result in excessive costs due to unnecessary diagnostic tests for evaluations of

maternal fetal health, even if the women's chief complaint upon presentation to the ED was unrelated (Ferriols Pérez et al., 2018; Thangarajah et al., 2018). Costs are higher for women who use unscheduled care during the prenatal period, including the ED, compared to women who do not (Magriples et al., 2008).

Fourth, increased costs are associated with a substantial increase in the volume of visits to the ED. Nationwide the total number of ED visits by Medicaid recipients increased from 128 million visits in 2009 to 143 million visits in 2018, with the steepest increase between 2008 and 2015 (Kellermann et al., 2013). Data from a United States national cohort study revealed that women were responsible for about 55% of all ED visits in the country (Moore & Liang, 2020). For women aged 15 to 65, pregnancy-related diagnoses are the fifth most common reason for ED visits (Cairns et al., 2018). Concerns about the volume of ED visits used for care, rather than for true emergencies, are only heightened for policy officials given the historical patterns of higher ED use among Medicaid recipients juxtaposed against the Medicaid expansion efforts across the United States beginning in 2014. Study results are mixed as to whether ED utilization has increased in those states that opted to expand Medicaid in 2014 (Daw & Sommers, 2019; McConville et al., 2018; Moghtaderi et al., 2021; Nikpay et al., 2017; Pines et al., 2016; Sun et al., 2018). As trend data become available, more studies support that ED utilization has increased in states with Medicaid expansion waivers, thus accentuating the need to systematically study patterns of ED utilization (Graves et al., 2019). Since the expansion of Medicaid in 2014, the proportion of women of reproductive age continuously insured through Medicaid has increased, including preconception, during pregnancy, and postpartum coverage (Daw et al., 2020). Studies indicate that associated with

increased coverage is an increase in prenatal care utilization and preliminary data have also demonstrated improvements in maternal infant outcomes (Wherry 2016; Clapp, 2019). With measured increases in utilization and insurance continuity during the prenatal period, changes in ED utilization during pregnancy compared to data prior to the policy shift has not been studied.

For all of the reasons noted above, understanding ED utilization patterns and predictors for this unique population are necessary to design and align comprehensive and quality services to support the needs of this population. It is acknowledged that ED utilization varies widely across populations and individuals (Oleske, 2001). Relative to other populations, few researchers have investigated ED utilization by Medicaid beneficiaries during the prenatal period. Without information on unique patient populations, policy and clinical interventions focused on providing comprehensive quality care remain uninformed and inadequate (Althaus et al., 2011; Flores-Mateo et al., 2012; Kumar & Klein, 2013; Morgan et al., 2013). Most studies of ED use over the last decade have focused on ED use by specific non-pregnant populations such as the elderly, adolescents, children, patients with drug and alcohol abuse problems (Ginde et al., 2012; Hackman et al., 2006; McCusker et al., 2003; Moulin et al., 2018) and disease types whether chronic or acute (D'Onofrio et al., 2006; McGeary & French, 2000).

This dissertation aims to further explore, define, and analyze ED utilization by pregnant women who are enrolled in Medicaid. Such population-specific studies are needed to provide data to support recommendations on actions targeting both the service and the policy level to deliver coherent, efficient, and effective care (Chen & Ayanian, 2014; Foley et al., 2013; Oleske, 2001; Sultz & Younge, 2011; Tang et al.,

2010). The research questions and methodology are described in Sections 1.2 and 1.3, respectively.

## **1.2 Research Questions**

This dissertation used a framework adapted from Anderson (1995) that conceptualizes health care utilization by focusing on how individual characteristics and the three categories of individual determinants – predisposing, enabling and need – explain health care utilization (Andersen, 1995; Andersen, 2008). This framework was adapted to examine the characteristics, patterns, and factors contributing to ED utilization among pregnant women enrolled in Medicaid. Specifically, the major research questions addressed in this dissertation were:

- To what extent do current Medicaid beneficiaries utilize the ED during pregnancy?
- What are the characteristics of pregnant Medicaid recipients who use the ED during the prenatal period?
- What sociodemographic, clinical, and behavioral factors are associated with the number of ED visits (count) among Medicaid beneficiaries during pregnancy?

## **1.3 Research Methodology**

To answer these questions, this dissertation utilized Medicaid data collected in the state of Delaware over a five-year period (fiscal year 2007 - 2012) from pregnant women. Independent variables of interest were selected, constructed, and modeled using the Medicaid claims data including but not limited to, data on demographics, Medicaid enrollment characteristics, days on Medicaid during the prenatal period, and

medical risks, as well as an assessment of urgent versus non-urgent ED use. Analytic techniques included standard descriptive and regression analyses used for count data. All hypotheses were deemed statistically significant if a p-value  $< 0.05$ . Data management and analyses were conducted using Statistical Analysis Software (SAS) Version 9.4 (SAS Institute Inc., Cary, NC) and Stata Statistical Software version 17 (Stata Corp. *Stata Statistical Software Release 17*. Stata Corp LLC College Station, TX).

#### **1.4 Ethics Approval**

This study was approved by the University of Delaware Institutional Review Board (UDIRB #482092).

#### **1.5 Organization**

Following this introduction, the second chapter presents the literature review and the conceptual framework that provided the foundation for this health-care utilization study, including the theoretical and methodological issues associated with applying the framework for this patient population. The third chapter transforms the conceptual framework presented in Chapter 2 by defining the model specification for the study, including definitions for the dependent variable, ED use, and the independent variables. The fourth chapter presents the empirical results of the study from the regression model. The fifth chapter summarizes the findings and offers an example of how the findings can be applied. The sixth chapter highlights the study's strengths, the study limitations, future research, and related policy implications.

## **Chapter 2**

### **LITERATURE REVIEW AND CONCEPTUAL MODEL**

Chapter 2 lays the foundation for this study by reviewing both the literature and the conceptual model used for this dissertation. Section 2.1 provides a review of the literature. Section 2.2 summarizes the research gaps. Section 2.3 describes the conceptual framework that serves to undergirds the findings from the literature about ED utilization by pregnant Medicaid beneficiaries and forms the foundation for the dissertation's purpose and approach. Section 2.4 offers a brief summary of this chapter.

#### **2.1 Literature Review: Overview**

EDs are a key component of the United States ambulatory health care delivery system. Approximately 70% of all hospitals across the US have an ED with a physician on site 24 hours a day; a much smaller percentage of hospitals have standby EDs with a physician on call; and even less are designated as comprehensive EDs with physicians and subspecialties available 24 hours a day. A subset of EDs are further designated as a trauma centers and rated on a scale of 1 to 4 depending on what service capabilities are available.

Traditionally, patients accessed the ED for injury, trauma, and acute conditions. However, over the past decade, EDs have evolved to not only provide care for those in need of immediate attention, but to patients who seek care for minor conditions. Patients may have a primary care provider but cannot be seen, and/or care

is simply not available due to a variety of factors that impede access (Morganti et al., 2013; Pitts et al., 2010; Iglehart, 2013).

In the US health care system, the ED is uniquely situated as the only place in the health care system where hospitals have a statutory requirement under the Emergency Medical Treatment and Active Labor Act (EMTALA) to meet the needs of patients who come to the ED for care, irrespective of their ability to pay or their citizenship (Iglehart, 2013; Rosenbaum, 2013). Among health-care policy researchers, it is referred to as the “safety net of the safety net” (Morganti et al., 2013). Compared to primary care, EDs, regardless of the classification, are resource intensive and costly. Given increases in ED utilization and associated costs, research regarding ED use and access has accelerated since an Institute of Medicine (IOM) report identified EDs as a service delivery site at the “breaking point” (Institute of Medicine, 2007).

Although data from a US national cohort study revealed that women were responsible for about 55% of all ED visits, and pregnancy-related diagnoses are the fifth most common reason for ED visits and the fourth most common ED discharge diagnosis code among women aged 15 to 65 (Cairns et al., 2018; Moore & Liang, 2020), the literature search results revealed relatively little research has been published about ED utilization among pregnant women. Based on the review of the literature on ED utilization, some researchers explored whether women accessed the ED or not using a variety of study questions and independent variables (Clements et al., 2018; Cunningham et al., 2017; Gavin et al., 2006; Ismailova et al., 2022; Lee et al., 2009; Malik et al., 2017; Matteson et al., 2008; Varner et al., 2020); others studied whether pregnant women were frequent or infrequent visitors to the ED (Mehta et al.,

2017; Vladutiu et al., 2019); and still others looked at whether ED visits were urgent or non-urgent (Ferriols Pérez et al., 2018; Kilfoyle et al., 2017; Varner et al., 2020; Xu, F. et al., 2017). Of interest, none of the studies used a methodology appropriate for count data to predict the number of ED visits among pregnant women during the prenatal period. See Appendix B for the literature review search strategy and tables that summarize the studies in the literature.

Regardless of how researchers have defined and studied ED utilization over the past 15 years, it seems clear that accessing the ED during pregnancy is common. Rates of utilization in published studies revealed a range from as low as 20% and as high as 84% with considerable overlap in between (Clements et al., 2018; Cunningham et al., 2017; Gavin et al., 2006; Ismailova et al., 2022; Kilfoyle et al., 2017; Lee et al., 2009; Malik et al., 2017; Matteson et al., 2008; Mehta et al., 2017; Vladutiu et al., 2019; Xu et al., 2017). Several authors reported between 12% and 58% of women made more than one visit (Cunningham et al., 2017; Magriples et al., 2008; Mitra, Parish, Clements, Zhang, & Simas, 2018b; Vladutiu et al., 2019; Xu et al., 2017). Vladutiu (2019) reported that a higher proportion of visits occurred in the afternoon and early evening. More women used the ED later in the pregnancy (Vladutiu et al., 2019), albeit not all studies agreed with the later finding and report that a higher proportion of ED visits occur early in pregnancy (Mitra et al., 2018; Varner et al., 2020; Xu et al., 2017).

ED visit rates likely varied depending on ED use variable definitions, such as whether authors elected to: (a) include hospital ED service locations as well as specialized ED sites for pregnant women, generally known as obstetric emergency departments and/or obstetric triage units (Kilfoyle et al., 2017; Magriples et al., 2008;

Matteson et al., 2008; Vladutiu et al., 2019); (b) consider only ED visits that did not result in hospitalization (Lee et al., 2009; Vladutiu et al., 2019); or (c) truncate the prenatal observation period as opposed to including the full prenatal period (Lee et al., 2009). In addition, most US-centric data were collected at least 6-10 years prior to the study publication. One study used data from as far back as the mid-1990s (Gavin et al., 2006); the most recent study data were from 2012 (Kilfoyle et al., 2017). These differences in the time periods during which data were collected may also account for differences in ED utilization rates.

### **2.1.1 Organization of the Literature Review**

Researchers have studied predictors of ED utilization from various perspectives. The following five sections synthesize the literature with respect to predictors of ED use by pregnant women. Section 2.1.2 describes studies that explored general characteristics of pregnant women who use the ED. Section 2.1.3 reviews studies that focus on the subset of women who use the ED frequently (high utilizers). Section 2.1.4 reviews studies in the literature that examined differences in EDs visits that were defined as urgent and non-urgent. Section 2.1.5 reviews studies that examined the impact of comorbidities on ED use for this patient population, followed by section 2.1.6, a review of evidence that describes why women are motivated to visit the ED.

### **2.1.2 ED Utilization: Sociodemographic Indicators**

Over the past decade, researchers have focused on defining predictors of ED utilization by investigating utilization by disease types, whether acute or chronic, as well as by patient populations ranging from infants to geriatrics. For each sample

population, sociodemographic factors such as gender, race, insurance status, education, marital status, employment, and income are often key variables included in the analyses. Some of these same variables may provide insights into ED use as they relate to pregnant women. For example, age may impact ED use given that pregnant women under age 20 years and greater than 35 years have more complications related to pregnancy, which in turn may lead them to use the ED more (Ely & Driscoll, 2021). The impact of marital status is another variable that is often studied in the context of pregnancy, pregnancy utilization, and pregnancy outcomes. Lack of partner support leads to decreased prenatal care visits, which in turn may lead to an increase in ED utilization (Cohen, K. et al., 2016). Other factors predicting ED utilization for this population may be similar to findings from the general non-pregnant population such as the phenomenon that ED use in rural areas, particularly for treat and release visits, is outpacing ED utilization rates in urban areas. Researchers hypothesize that the increase in ED use in rural settings may be attributed to lack of access (Greenwood-Ericksen & Kocher, 2019). Several ED utilization studies that included some of these variables to predict ED use during the prenatal period are synthesized in the following paragraphs.

In a retrospective, cross sectional study of over 650 women who delivered a live birth in Michigan, being an adolescent (younger than 20 years) was associated with ED use. As noted above, this may be explained by studies that showed younger women under age 20 years have more complications related to pregnancy, which in turn may lead them to utilize the ED more (Malik et al., 2017). In a population-based study of over 154,000 pregnant women in New South Wales, Xu et al. (2017) also reported higher ED visit rates in women less than 20 years of age; the study also

showed that ED visits significantly declined with age. In other studies, Vladutiu reported ED rates highest among women ages 20 to 24 years in a study of over 100,000 women; Varner and colleagues also reported that younger age, in this case less than age 25, was associated with ED use in a large cohort of over 2 million pregnant women, aged 10-55 (Varner et al., 2020; Vladutiu et al., 2019). None of the studies revealed an increase in ED use associated with older age, although it is hypothesized that advanced maternal age would increase ED use given the increased risk of complications related to pregnancy.

Age is an important variable to investigate and may explain ED utilization, however, one must look closely at the research designs. For example, Varner (2019) included women with any reported pregnancy, regardless of outcome which may capture women who have abortions or miscarriages. Malik, Xu, and Vladutiu selected women who delivered a live birth. Second, although the Malik study implied that pregnant women across all ages were included in the study, the authors did not specify the age range of the study population. Rather, age was presented as a stratified variable noted as less than or greater than/equal to 20 years of age.

A few studies examined the impact of race/ethnicity on ED utilization; of those, all reported that non-white race was associated with ED utilization (Malik et al., 2017; Vladutiu et al., 2019). A third study of 233 women utilizing ED services at an Obstetrics and Gynecology hospital in the US, did not find that race was associated with ED use, however, speaking a language other than English at home was associated with ED utilization (Kilfoyle et al., 2017). If one assumed those speaking a language other than English were immigrants, this finding differs from findings by Varner and colleagues, as well as Xu and colleague. In those studies,

having non-immigrant status, defined as Canadian born or Australian born, respectively, was associated with ED use whereas immigrant status (foreign born) was not (Varner et al., 2020; Xu et al., 2017).

Studies that included women covered by either private, public, or those who were uninsured, revealed that Medicaid beneficiaries were more likely to use the ED compared to those with private insurance or those without insurance (Kilfoyle et al., 2017; Malik et al., 2017; Varner et al., 2020; Vladutiu et al., 2019; Xu et al., 2017). Similarly, two investigations reported that lower income was also associated with ED utilization for women enrolled in national health care systems (Kilfoyle et al., 2017; Malik et al., 2017; Varner et al., 2020; Vladutiu et al., 2019; Xu et al., 2017). Continuing to investigate ED utilization by insurance status and income remains relevant as health-care access and health care policies change the landscape of utilization.

Two studies reported results as to whether area of residence impacted ED use. In a large population cohort of pregnant women accessing prenatal care in Canada, findings revealed ED use highest in rural areas. However, in a large study of Medicaid beneficiaries in North Carolina, the authors reported ED rates were lowest in rural areas (Varner et al., 2020; Vladutiu et al., 2019).

Health policy researchers emphasize that understanding sociodemographic predictors by population are important to understanding utilization in order to accurately focus policy and program interventions (Sommers et al., 2012). Including and stratifying for variables such as race, age, insurance status, and geographic residency provide valuable information about ED utilization and also serve as measures of health equity which may explain ED utilization (Bingham et al., 2019).

### **2.1.3 ED Utilization: Maternal Health Risks, and Prenatal Care**

Maternal health risks are often included in perinatal research studies given their association with adverse maternal and infant outcomes. Researchers included maternal health risks in analytic models as predictors of ED use. One study revealed that prenatal smoking, use of recreational drugs, and history of domestic abuse increased the odds of ED use (Malik et al., 2017). Similar findings were reported in two large population-based studies in North Carolina and Australia with respect to prenatal smoking (Vladutiu et al., 2019; Xu et al., 2017).

Prenatal primary care provider credentials, pregnancy health history, and inadequate prenatal care have also been associated with increased ED use. Researchers hypothesize that lack of access to prenatal care may explain why some women seek care at the ED and several studies have demonstrated that less than adequate prenatal care has been associated with ED use (Magriples et al., 2008; Malik et al., 2017). Late entry into care was also associated with ED utilization, potentially reflecting a disengagement with the health care system in general. Varner and colleagues reported that women experiencing a first-time pregnancy and receiving antenatal care from a provider other than an obstetrician were associated with increased ED utilization (Varner et al., 2020).

### **2.1.4 ED Utilization among Pregnant Women with Disabilities**

Prior to 2018, only one study examined ED utilization among women with disabilities and reported that women with disabilities were more likely to have at least one ED visit compared to women without disabilities (Gavin et al., 2006). In Gavin's study of over 214,000 women enrolled in Medicaid across four states, the percent of women with disabilities ranged from 1.1% in Florida and Texas to 1.4% and 1.8% in

New Jersey and Georgia, respectively. The adjusted odds of women with disabilities of having at least 1 ED visit ranged from 1.2 to 1.6 times the odds of women without disabilities across the four states. In the past five years, several studies have examined ED utilization subsequent to a National Institutes of Health (NIH) call for studies to investigate pregnancy, delivery and postpartum risks associated with having a disability (Clements et al., 2018; Mitra, Parish, Clements, Zhang, & Simas, 2018a). Clements et al. (2018) studied ED use among a cohort of 221,000 women who delivered in Massachusetts between 2007 and 2009. Findings revealed that women in a medium/high risk category for presumed disabling conditions utilized the ED more compared to those with a no/low risk (37.1% versus 25.0%). Mitra and colleagues (2018) studied the prevalence of ED utilization in a cohort of women of with intellectual and developmental disabilities (IDD). Findings revealed that women with IDD visited the ED more compared to women without IDD (56% versus 29%). Of note, both Gavin (2006) and Mitra (2018) reported that women with disabilities entered prenatal care later than women without disabilities. Mitra (2018) also reported that once women with IDD started prenatal care, they accessed services more often than women without disabilities.

While all three studies reported women with disabilities were more likely to use the ED, the study methodologies varied. Gavin (2006) identified women with disabilities using the Medicaid eligibility pathways codes. Clements et al. (2018) studied ED use among women using the Access Risk Classification System (ARCS). The ARCS includes a comprehensive list of diagnoses and conditions that classifies individuals based on presumed risk, rather than actual risk. Four percent of the sample were classified as medium to high risk. Mitra (2018) studied ED use in a

cohort of women with intellectual and developmental disabilities (IDD) only. Women with IDD were identified from a state claims-based dataset of all women who 2003 to 2009 using an ICD-9 code algorithm. Given that less than 1% of women were identified as having IDD, the study authors used a 3:1 matched design to construct the sample.

The sparse number of publications illustrates that few studies have investigated ED utilization across the spectrum of women with physical, sensory, intellectual and developmental, and psychiatric disabilities. As the proportion of pregnant women with disabilities increases, describing ED use is important for several reasons. First, women with disabilities have higher rates of chronic health conditions and higher rates of pregnancy complications, hence ED use may increase. Second, ED use by pregnant women with disabilities may reflect existing structural social and environmental determinants. For example, clinicians are often not trained to care and support women with disabilities; other issues, such as office set ups that are not adapted for women with some types of disabilities may affect access (Goldacre et al., 2015; Horner-Johnson et al., 2017).

### **2.1.5 High Utilizers versus Low Utilizers**

Some maternal reproductive health researchers and epidemiologists have focused research on the subset of women who use the ED frequently and therefore responsible for a higher cost burden. In a population of women enrolled in Medicaid, Mehta et al. (2017) examined differences among pregnant women enrolled in Medicaid who presented to an obstetric triage unit for unscheduled visits during the prenatal period. Equal numbers of high utilizers ( $n = 20$ ), defined as women who had reached at least 16 weeks' gestation or greater with four or more unscheduled visits to

the obstetric triage unit, and low utilizers (n = 20) defined as women who had reached at least 36 weeks' gestation without frequent use of unscheduled visits, were enrolled in the study. Data were collected using semi-structured interviews, validated scales, and clinical data (Mehta et al., 2017). Results revealed that high utilizers were more likely to report they faced barriers to perinatal care. Interview data also revealed the underlying reasons high utilizers sought ED care at the obstetrical triage unit were related to psychosocial vulnerabilities (such as, adverse childhood experiences, dysfunctional relationships and distrust, express limited coping strategies to address challenges of pregnancy, and continued anxiety about the current pregnancy) or preexisting illness and concern about symptoms. However, there were also similarities between the two groups. Interviews revealed both groups expressed frustration at system-wide issues related to accessing prenatal care including the fact that the ED triage unit was more accessible than outpatient care. Examples of why this was true included that the triage unit was more convenient, accepted walk-ins, had staff to manage the volume, and was able to deal with issues such as interruptions in insurance coverage. In addition, findings revealed no difference in the baseline sociodemographic variables evaluated across the two utilization groups including: age, race, education, sexual orientation, relationship status, insurance status, and the obstetrical triage acuity score at the time of the ED visit.

Validity et al. (2019) also examined the differences among pregnant women who visited the ED  $\geq 4$  times and those who visited the ED  $< 4$  times. Using a study population of over 75,000 women enrolled in Medicaid for most of their pregnancy, the study authors examined selected predictors in women who used the ED frequently ( $\geq 4$  visits) and those who did not. Findings revealed that characteristics associated

with high utilization included: multiple pregnancy, and one or more maternal comorbidities. Demographic predictors included younger women (20-24 years), Black race, married, and lower education. Several maternal behavior factors including prenatal tobacco or alcohol use. Findings also revealed that high utilizers were more likely to deliver a premature infant. As noted above, Meta et al. (2017) found no differences in baseline characteristics between those who used the ED frequently and those who did not. This may be explained by the small sample size with only 20 subjects in each group.

By investigating the demographic and psychosocial characteristics, maternal health risks, and maternal-clinical drivers for the subset of women who use the ED frequently, researchers may explain the health care seeking behaviors of the subset of pregnant women who use the ED on a frequent basis and initiate interventions to reduce excessive use.

#### **2.1.6 Urgent versus Non-urgent ED Visits**

Appropriateness of ED use has been studied in the context of non-pregnant and pregnant populations. In non-pregnant populations, researchers have examined determinants of ED use to understand whether excessive demand can be explained by those who use the ED for non-urgent care as opposed to urgent care (Durand et al., 2012; Uscher-Pines et al., 2013). As with non-pregnant populations, several studies explored ED utilization where pregnant women access the ED for non-urgent visits. Kilfoyle et al. (2017) sought to identify predictors associated with non-urgent ED use in a cross-sectional study of 233 women who delivered at an obstetrics and gynecology teaching hospital. In this study, the authors defined an urgent ED visit in the publication as meeting any one of four criteria: (1) it resulted in a hospital

admission or transfer to another facility; (2) more than one liter of intravenous fluids was received; (3) intravenous medications were administered; or (4) the chief complaint at the time of the ED visit was a sign of a pregnancy complication or labor. Two criteria the authors considered in their definition but did not use because they could not reliably determine the information from the medical records were whether the participant's provider referred the patient to the ED, and the Emergency Severity Index score. Of the 233 participants in the study, 83 cases (35.6%) visited the ED one or more times for a non-urgent indication. The remaining 150 women were classified as "without non-urgent ED use"; they included 114 women who met the definition of an urgent visit and 36 women who had no record of an ED visit. While multiple variables were significantly different in the unadjusted model, only primary language spoken in the home other than English and having public/no insurance compared to private insurance, were significantly associated with urgent ED use.

In a study of 668 women visiting an ED in Spain, 61% visits were classified as not necessary or moderately necessary using a classification scheme developed by the on-site researchers and clinical staff. As pregnancy advanced, more ED visits were more likely to be necessary. The study authors included a variety of sociodemographic or maternal health history variables, including maternal events such as previous preterm deliveries or miscarriages, that they hypothesized would increase ED utilization due to anxiety and concerns. However, none of the maternal events were associated with visits deemed to be necessary (Ferriols Pérez et al., 2018).

Researchers have also investigated whether non-urgent ED visits result in hospitalizations. In a descriptive study of 173 women triaged as having a non-urgent

condition, 86% were treated and released and 14% were admitted (Matteson et al., 2008). Last, Thangarajah investigated whether there were differences in women who presented to the ED with a physician referral versus those who did not have a referral. Of those with a referral, approximately 50% were admitted compared to 23% who arrived at the ED without a referral (Thangarajah et al., 2018) potentially indicating those with referrals were pre-assessed by their primary care giver as having more urgent needs.

Using the ED for non-urgent reasons increases cost and overcrowding. In turn, overcrowding leads to delays in accessing appropriate treatments, decreased quality of care, and poorer outcomes for those needing emergency care (Morley et al., 2018). Identifying women who seek care at the ED for non-urgent conditions may offer insights into how to improve the system to offer more comprehensive, efficient, and timely care at appropriate settings, while at the same time save costs and prevent overcrowding.

### **2.1.7 Comorbidities**

Several studies have examined the presence of preexisting health conditions and/or the development of comorbidities during pregnancy as predictors of ED use. Cunningham et al. (2017) were the first to explore the association between maternal comorbidities and ED utilization among pregnant women during the prenatal period (Cunningham et al., 2017). In a retrospective cohort study, the study authors accessed medical claims data from a multi-payer database that included pregnant women enrolled in private insurance provided by employers. Study data included prenatal and delivery claims from 157,786 women, aged 18 to 44 years, who delivered a live birth in a hospital setting between January 2010 through December 2011. Women had

continuous insurance coverage in the 10 months prior to delivery. Using ICD-9 codes, Cunningham et al. (2017) identified cases with the following comorbidities: obesity, diabetes, gestational diabetes, hypertension (including preeclampsia and eclampsia), and asthma. Findings revealed that 21% of women who did not access the ED had one or more comorbidity compared to 30% of women who accessed the ED. After controlling for age and region, the adjusted odds ratio revealed that women with any maternal comorbidities were more likely to use the ED. Increased odds of seeking ED use were highest for those with asthma, followed by obesity, hypertension, diabetes, and gestational diabetes.

Varner (2020) also found that a higher number of comorbidities was associated with ED use. Results revealed that morbidities preconception led to increased ED utilization during pregnancy. Women with comorbidities were more likely to utilize the ED compared to women with none or little comorbidities (Varner et al., 2020).

None of the studies investigating the impact of comorbidities on ED utilization used available indices that provide a composite score to measure disease burden. One of the most widely used indices to measure disease burden among adults is the Carlsson Comorbidity Index. This index has been used across a wide range of clinical, epidemiological, health service, and health policy research studies to predict morbidity, mortality, prognostic impacts of disease burden, and determining resource use. The index has been cited in more than 9,500 publications (Charlton et al., 2014). While the index has not been used to determine ED use among pregnant women, the index has been used to predict patients who are at high risk of incurring health-care resources (Carlsson et al., 2014). More recently, Bateman et al. (2013) developed the

Obstetric Comorbidity Index to measure the maternal health risks of pregnant women. The index includes relevant obstetrical conditions and provides a summary estimate of the burden of maternal comorbidities. In a systematic review of the literature on the measurement properties of comorbidity indices, Aoyama et al. (2017) concluded that Obstetric Comorbidity Index was the most appropriate index for use to conduct maternal health research, particularly with health administrative datasets. The index has subsequently been used to measure the burden of maternal disease to predict outcomes across a variety of maternal health research studies (Bliddal et al., 2020; Easter et al., 2019; Metcalfe et al., 2018; Somerville et al., 2019) but it has not yet been used to study ED use.

Understanding how comorbidities impact ED utilization can assist in developing and strengthening care coordination, which in turn may lead to decreasing ED use. Using indices that provide a single composite score rather than creating a list of comorbidities of interest may be an efficient approach to understand the association between ED uses and comorbidities.

### **2.1.8 Behavioral Drivers of ED Use by Pregnant Women**

Several studies sought to understand the motivating factors behind a woman's decision to use the ED. Most studies asked women to identify reasons they presented to the ED. In a study of women attending a dedicated obstetric ED at a large university hospital, Matteson et al. (2008) provided insights into why EDs were used from the perspective of the pregnant women. In this study, 173 pregnant women, who were triaged as non-urgent, were asked about their reasons for accessing the ED. Analyses were stratified according to whether the pregnant women had reached less than 20 weeks' gestation or more than 20 weeks' gestation. Approximately 20% of

the women in each group reported using the ED due to issues related to access. Women at less than 20 weeks' gestation were more likely to report having felt they were experiencing a true emergency compared to those at greater than 20 weeks' gestation. On the other hand, women at more than 20 weeks' gestation were much more likely to report being told to go to the ED by their primary caregiver, compared to those at less than 20 weeks' gestation. Thangarajah (2018) also reported on reasons for ED visits. In a study of 331 pregnant women seeking care at a tertiary institution in Germany, 45% of women presented to the ED with a referral from their physician with the remainder coming to the ED without a referral. In a study at a single site in the US, 45% of believed their symptoms constituted a medical emergency; 36% reported being told to go to the ED by their health care provider; and 13% of the participants reported that they went to the ED because they could not access a primary prenatal care provider (Kilfoyle et al., 2017).

Magriples and colleagues also studied why pregnant women were motivated to visit to the ED. The authors collected psychosocial measures of self-esteem, depression, social support, social conflict, prenatal distress, pregnancy symptom discomfort, prenatal care satisfaction, prenatal care knowledge, and readiness to care for the baby using various self-administered instruments. The results revealed that women with high-symptom distress used the ED more. However, motivations to visit the ED may depend on multiple factors including history of previous pregnancies. For example, the findings in the Magriples study may be explained by that fact that the sample was limited to low risk, younger women who may be less familiar with symptoms associated with pregnancy (Magriples et al., 2008).

Seeking service at the ED may be attributed to multiple reasons. In addition to lack of access, being referred, or feeling like they were experiencing a medical emergency, women may seek care at the ED because it is a familiar setting, or the ED offers non-judgmental care where insurance is not a defining factor with respect to receipt of care. Other reasons may include lack of information about how to interpret normal signs and symptoms associated with pregnancy, although one study revealed prenatal counseling was associated with an increase in ED utilization (Ismailova et al., 2022).

## **2.2 Research Gaps**

This comprehensive literature review reflects the sparseness of the available data on the ED use and usage patterns pregnant women during the prenatal period. Despite evidence from the literature supporting the fact that ED use is common during the prenatal period, little is known about the frequency and drivers and there remain areas of conflicts and gaps.

First, all studies elected to operationalize ED use as a dichotomous variable thus truncating valuable data, rather than using a methodology that is appropriate for count data. If ED visits were operationalized as discrete numbers of visits (i.e., 0, 1, 2, 3...) rather than as a binary variable, more information about ED use would be provided. Even studies focused on ED frequency have tended to dichotomize high utilizers as those with more than three visits and low utilizers as those with fewer than four visits (Vladutiu et al., 2019), rather than using the frequency of visits obtained through use of an appropriate methodology for count data.

Second, study designs and interpretation of findings were hampered by small samples (Kilfoyle et al., 2017; Magriples et al., 2008; Matteson et al., 2008;

Thangarajah et al., 2018). Several studies conducted secondary analyses using convenience samples from intervention studies with specific inclusion criteria that required informed consent, thus introducing a potential bias for the secondary analyses that was focused on ED use. In addition, smaller studies limit generalizability across other settings. Several studies that used national and/or regional data overcame the limitations of single site studies and linked their data to other data sources (Vladutiu et al., 2019); however, some of these studies were descriptive in nature (Lee et al., 2009) or did not have access to important maternal characteristics such as race (Cunningham et al., 2017).

Third, given the limited number of studies, there is little agreement about the drivers of ED use as they pertain to demographic and psychosocial characteristics, maternal health risks, and maternal-clinical predictors. Study designs, including how study populations were selected and variable definitions varied across studies. In addition, where subjects accessed care such as studies that used obstetric triage units, in addition to ED service sites, may yield valuable information if data were analyzed by type of service unit.

Fourth, little is known about the impact of maternal comorbidities. Several recent studies have examined comorbidities, although they have approached the questions of what to study and how to establish risk in a variety of ways. In most studies, authors chose a mix of preexisting and/or pregnancy-related medical comorbidities and/or risk behaviors. For example, Cunningham et al. (2017) chose obesity, hypertension, diabetes, and gestational diabetes which they considered the most “common” comorbidities during pregnancy. In another study, which also used Medicaid claims data, the authors chose to screen for 11 comorbidity variables as the

independent variables (Vladutiu et al., 2019). Gavin et al. (2006) chose to include 14 preexisting medical conditions and 16 pregnancy complications in the model to predict ED visits. Each was evaluated as individual explanatory factors, before being specified in the model as a dichotomous variable. Of interest is that none of the studies to date have used data reduction instruments, such as the comorbidity indices, that are available to characterize maternal health risks, in order to study the impact of comorbidity and ED use (Aoyama et al., 2017) Using indices such as Elixhauser, Charlson, or the Obstetric Comorbidity Index has been reported in the literature as useful for tools identifying health risk, resources, and health care service utilization. Such tools have been used in clinical, epidemiology, health service and health policy studies.

Last, while most studies describe clinical claims about ED visits, only one study attempted to discern appropriateness of use by classifying visits as urgent or non-urgent (Kilfoyle et al., 2017). The results of that study revealed only two sociodemographic factors significantly associated with urgent ED use, leaving the authors to wonder about whether there is interrelatedness among the independent variables and therefore cannot be used to provide results (Kilfoyle et al., 2017). Some authors provided descriptive information on the number of subjects that were hospitalized as an indication of urgent and non-urgent ED use but did not include them in a model. Other authors acknowledged that appropriateness of ED use was important to research; however, they did not operationalize how to study urgent and non-urgent use. Some did not include ED visits that resulted in hospitalization in their studies (Lee et al., 2009; Magriples et al., 2008; Vladutiu et al., 2019). Aside from reducing health care cost, identifying the number and reasons for non-urgent care can

assist in identifying potential weaknesses across the prenatal care system that can be addressed so women get timely, comprehensive care at the appropriate setting.

In summary, with these gaps in mind, this dissertation was designed to focus on ED utilization among pregnant women, a population with special needs and health care seeking behaviors that has not been studied extensively. The study described the extent to which pregnant women enrolled in the Delaware Medicaid program used the ED, the characteristics of those women, and the sociodemographic and clinical variables that contributed to the number of ED visits among the study population. The study population was selected using data from more than 20,000 Medicaid beneficiaries who delivered over a 5-year period. State level Medicaid data offers insights into how Medicaid beneficiaries in the state are accessing care and in turn can be used to inform how programs need to be developed, altered, or strengthened at the state-level. Last, the analysis operationalized ED visits as a discrete number (i.e., 0, 1, 2, 3...) rather than truncating data as a binary variable as has been done in previous studies.

### **2.3 Epistemological and Conceptual Framework**

Although there is a long history of health policy and programming efforts to ensure that pregnant women have access to prenatal care and can reap the associated benefits, little is known about why women turn to the ED for care. Researchers and theorists from a variety of academic disciplines, including sociology, psychology, nursing, and economics have established that a variety of factors are likely to influence the kind of health-care-seeking behavior that is the subject of this dissertation. Health behavior and the decision to seek care at an ED during pregnancy may depend on risk perceptions (Weinstein & Nicolich, 1993); perceived barriers to

care (Janz & Becker, 1984; Rogers, 1997); confidence in one's ability to meet challenges (Bandura, 1977); or simply attitudes towards the behavior of seeking care (Ajzen, 1980). Further understanding of health-care-seeking behavior in the context of ED utilization and access is complex. Theories and models vary in how they define and measure the concept of access. In general, some access theories focus on equity and social justice, while others focus on utilization as a form of observed access. Of the various theories and models that include utilization, several attempt to explain access and use by considering stages of health-care-seeking behavior and emphasize the nature of the sick role and responses to signs and symptoms of illness. Others have developed models of interacting variables to explain health-care seeking behaviors (Andersen, 1995; Andersen et al., 2014; Mechanic, 1978; Parsons, 1951; Rosenstock et al., 1994; Suchman, 1965). Given that pregnancy is a normal physiological process, sick role/illness theories are less applicable to this population.

For this reason, issues of access are the impetus for many investigations. Researchers study the underlying reasons of access and utilization by investigating determinants and predictors of access across populations and service delivery settings and how access impacts health outcomes, otherwise defined as effective access. Researchers also investigate the relationship between the associated costs and the access provided, with the intent to measure how health can be improved at a minimal cost. This is referred to as efficient access (Andersen et al., 2014). It is the hope that the results of such studies will help to differentiate between effective access, that is, actual access that is associated with positive health outcomes, and efficient access defined as actual access that is associated with positive health outcomes and cost-effective delivery (Andersen et al., 2014).

This dissertation uses a conceptual framework adopted from Andersen and colleagues to elucidate characteristics, patterns, and predictors associated with ED utilization during the prenatal period for Medicaid beneficiaries (Andersen, 1995; Andersen, 2008). In his Behavioral Model of Health Services Use, Andersen argues that the primary determinants that influence health-care utilization are contextual and individual characteristics (Figure 1.1). In turn, use is associated with health outcomes. This model was chosen because it: (i) includes interacting determinants of access and use; (ii) explicitly references use of personal health-care services as one of the variables; and (iii) addresses the distinction between perceived and evaluated need. Although the focus of this dissertation will be on individual characteristics, the full model clearly shows the dynamic and iterative nature of health service use and will be valuable when reflecting on the study findings.

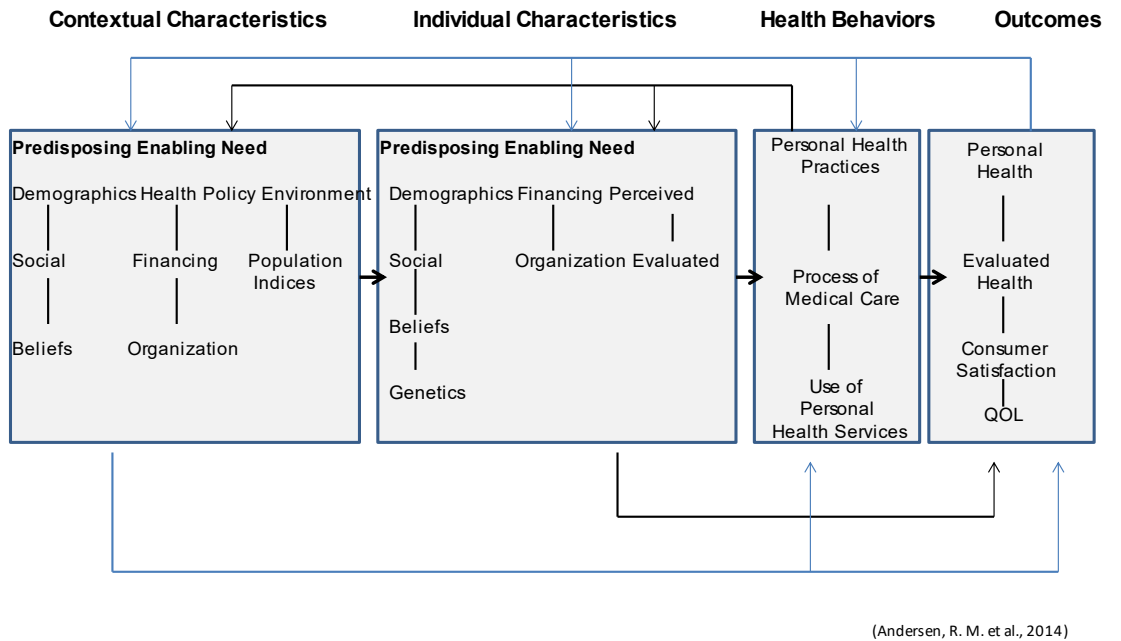
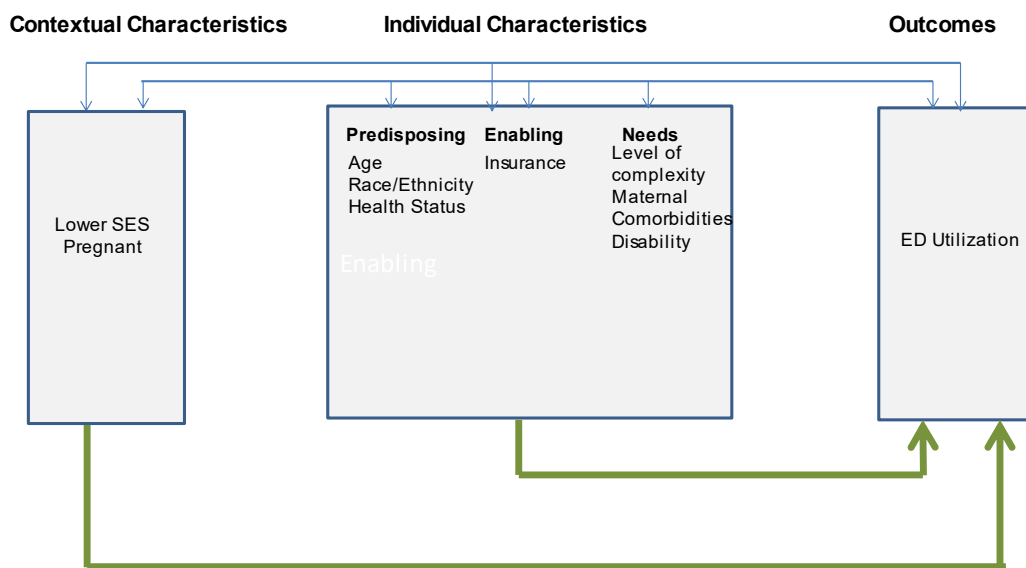


Figure 1.1: A Behavioral Model of Health Services Use

The centerpiece of the Andersen model that focuses on individual characteristics and the three categories of individual determinants – predisposing, enabling and need was adopted as the conceptual framework for this dissertation. See Figure 2.1.



(adapted from Andersen, R. M. et al., 2014)

Figure 2.1: Assessing Predisposing, Enabling, and Need Related Variables Using the Behavioral Model of Health Services Use

The individual’s predisposition for using services is captured by predisposing characteristics. Utilization may be explained by: (a) demographic characteristics (e.g., age, gender, and past illness); (b) position within the social structure (e.g., education, ethnicity, family structure, occupation, residence, language, hospital attended); and (c) knowledge, values, and beliefs around health service benefits. Andersen et al. would predict that an individual is more or less likely to use health services based on the three predisposing characteristics listed above. One may be motivated to seek out health-care services by virtue of life cycle or specific gender. For example, females,

by virtue of becoming pregnant, will seek out health services for prenatal care. The social structure, in turn, may influence one's ability to access resources to deal with health problems. A component of social structure is the physical space one is surrounded by and how healthy or unhealthy that space is. If a pregnant woman believes that health services are important for a positive neonatal outcome, she will be more likely to seek care. The predisposing factors in this dissertation include individual factors and social factors (see Figure 2.1).

Enabling characteristics refer to the resources or means that individuals have to enable them to access services. These can include individual, family or community resources that impede or facilitate access to health services. Common measures of enabling factors are income and financial resources, access to health insurance, social and emotional supports, and usual source of care. Other enabling factors reflect the surrounding environment, for example, where the patient lives, their housing structure, water sources, type of care, the spatial characteristics of the community (e.g., rural or urban) as well as travel and wait times. The enabling factors that might serve as determinants of use include the timeframe of insurance coverage (long-term versus short-term), and whether they have a usual source of care (see Figure 2.1).

The third dimension of the individual characteristics is need. Andersen and colleagues note that health-care utilization is influenced by the individual's perception of their need for services and their health status. Andersen acknowledges that such subjective perception about need may be juxtaposed against social and clinical perceptions of need that do not necessarily agree. Examples of need may be self-reported health risks, number of health conditions, and types of illnesses present.

Need factors in this dissertation will include comorbidities and level of complexity as it relates to the reason for the ED visit (See Figure 2.1).

## **2.4 Conclusion**

This chapter outlined published studies focused on the patterns of ED use by pregnant women during prenatal care, about the predictors of ED use by this population, and about the extent pregnant women use the ED for non-urgent conditions. Using data from a multi-year statewide Medicaid dataset, this dissertation explores each of these areas and, in so doing, fills a void that exists in the literature. To date, there is little research predicting the number of ED visits by pregnant women enrolled in Medicaid, or whether use is based on urgent needs. In the next chapter, the conceptual framework is transformed by defining the model specification for this study including definitions for the dependent variable, ED use, and the independent variables. The fourth chapter presents the empirical findings of the study.

## **Chapter 3**

### **STATISTICAL ANALYSIS METHODS**

As noted in the literature review in Chapter 2, there is limited agreement among researchers on the factors that explain ED utilization. In addition, actual estimates and predictors of ED use vary by study population and are influenced by the type of data, methods, and model used. This dissertation focused on predicting ED utilization (defined as the number of ED visits) during the prenatal period among pregnant women enrolled in the Delaware Medicaid program. The data relied exclusively on a Medicaid claims (billing) database from the state of Delaware. This chapter describes the analytic approaches used to model the data. The chapter is divided into four sections. Section 3.1 provides details about the data source and the study inclusion criteria. Section 3.2 details the dependent variable and the independent variables used in the study. Section 3.3 describes the theoretical model used for the ED count data and Section 3.4 specifies the model used in the study.

#### **3.1 Data Source and Study Inclusion Criteria**

##### **3.1.1 Data Source**

Data for this dissertation were provided by the University of Delaware Medicaid Research Program (UDMRP). Unique IDs were identified based on the presence of delivery-related claims using a case-finding definition provided by the United States Centers for Medicaid and Medicare Services data center. Data were provided by UDMRP for all women with a delivery related claim from July 2007

through June 2012. To adhere to data use requirements, data that could potentially identify the Medicaid individuals were not provided and all dates were de-identified.

Three de-identified data files were used for the study: a medical claims file, a client file, and a supplemental client file. The medical claims file provided information on clinical diagnoses as defined by the International Classification of Diseases-9 (ICD-9) codes, start and stop dates for each claim, and the care delivery service place. Data from the medical claims file were also used to describe and define events and conditions as well as to construct key variables including ED utilization and health status variables. The client file provided information related to Medicaid eligibility over time; these data were used to construct duration of Medicaid coverage for each case in the cohort. Data accessed from the supplemental client file included age and race/ethnicity, as well as eligibility pathway codes.

The constructed analytic dataset included Medicaid claims for all cases from the cohort during the time-period spanning July 2007 through June 2012 during the prenatal period. Prior to analysis, the dataset was rearranged from long format, where each record in the database contained information for a single claim, to a wide format where each record in the database contained all the information by each individual cases. All analyses were conducted using Stata Statistical Software version 17 (Stata Corp. *Stata Statistical Software Release 17*. Stata Corp LLC College Station, TX).

### **3.1.2 Study Inclusion Criteria**

The dataset provided by the UDMRP included more than 3.8 million records of billing claims from 24,044 unique Medicaid recipients. Data were restricted to women: (a) with a delivery-related code found in the key clinical diagnosis variable in the medical claims dataset providing evidence of a live birth, (b) of female gender

aged between 10 and 45 years, and (c) with Medicaid coverage data available. For those with more than one delivery event, only data associated with the first delivery of record were used. Using the study inclusion criteria noted above, the total number of unique IDs for the study cohort for this dissertation was 23,824. Claims used for this analysis were limited to prenatal period.

### **3.2 Dependent and Independent Variables**

Key variables used for this dissertation consisted of one dependent variable and eight independent variables. The dependent variable was constructed and operationalized to capture ED utilization (number of ED visits) by Medicaid recipients during the prenatal period. The independent variables used in this study were age; race; presence of disabilities; maternal general health risk; maternal obstetrical risk; ED visits resulting in hospitalization within 24 hours; duration of Medicaid coverage; and presence of a maternal-related diagnosis at the time of the ED visit. These variables represented the predisposing, enabling, and need dimensions of Andersen's health-care utilization framework and were used to explore ED use during pregnancy. Sections 3.2.1 and 3.2.2 provide a detailed explanation of all variables.

#### **3.2.1 Dependent Variable: Number of Emergency Department Visits**

In this study, the dependent variable was ED utilization during the prenatal period defined as the total number of ED visits. The ED visit variable was count data and was constructed for each case using the date of service and the service location. Claims were coded as "1," indicating that the service location was the ED, and "0," indicating that they were not associated with the ED service location. Unique ED visit

events were counted using start and stop dates of service, which provided a total count of ED visits for each case. In addition to location and dates of service, unique ED visits for each case were counted during the prenatal period as defined by the date of delivery and the beginning/end dates of Medicaid eligibility as parameters for the prenatal period.

Of the 23,824 cases in the study, 40.5% (9,649/23,824) utilized the ED at least once during their prenatal period. Among those who visited the ED, the total number of visits made over the course of the prenatal period was 22,883 (see Table 3.1).

Table 3.2 provides a detailed distribution of ED utilization by case and total number of ED visits. The number of ED visits by case ranged from 0 to 25 with one outlier at 83 visits collapsed into visit 25. As noted, the total number of ED visits was 22,883. Of those, 54.4% of the total ED visits were made by women who visited the ED less than four times. The remaining 45.6% were made by women who made four or more visits.

Table 3.1: Number of Cases with at Least One ED Visit Versus Number of Cases Without an ED Visit

Number of Cases With				Total Number of	
No ED Visit		At Least One ED Visit		Cases	ED Visits
14,175	59.5%	9,649	40.5%	23,824	22,883

Table 3.2: Number of ED Visits by Case and Total Number of ED Visits

Number of ED Visits	Number of Cases/Frequency	Percent	Total Number of ED Visits	Percent
0	14,175	59.5%	0	--
1	4,370	18.3%	4,370	19.1%

Number of ED Visits	Number of Cases/Frequency	Percent	Total Number of ED Visits	Percent
2	2,255	9.5%	4,510	19.7%
3	1,189	5.0%	3,567	15.6%
4	729	3.1%	2,916	12.7%
5	435	1.8%	2,175	9.5%
6	268	1.1%	1,608	7.0%
7	128	0.54%	896	3.9%
8	83	0.35%	664	2.9%
9	57	0.24%	513	2.2%
10	41	0.17%	410	1.8%
11	29	0.12%	319	1.4%
12	22	0.09%	264	1.2%
13	14	0.06%	182	0.8%
14	8	0.03%	112	0.5%
15	6	0.03%	90	0.4%
16	3	0.01%	48	0.2%
17	4	0.02%	68	0.3%
19	3	0.01%	57	0.2%
20	1	0.004%	20	0.1%
21	1	0.004%	21	0.1%
23	1	0.004%	23	0.1%
25 <sup>a</sup>	2	0.008%	50	0.2%
Total	23,824	100%	22,883	100%

<sup>a</sup>This includes one case with 83 visits coded as having 25 visits.

The average number of ED visits across the full cohort, including those with and without an ED visit, was 0.96. Of those who visited the ED, the average number of visits during the prenatal period was 2.37 (SD 2.03) with a median of 2.0 (see Table 3.3).

Table 3.3: Average Number of ED Visits

	Cases With		All Cases
	No ED Visits	At Least One ED Visit	
Mean	0	2.37	0.96
Standard Deviation	0	2.03	1.74
Minimum	0	1	0
Maximum	0	25	25
Total Number of ED Visits	0	22,883	22,883
Number of Cases (Percent)	14,175 (59.5%)	9,649 (40.5%)	23,824

### 3.2.2 Independent Variables

The eight independent variables included in the analytic dataset are described below.

#### Age

The subject's age was a static variable captured at the time of delivery. The descriptive data for age are listed in Table 3.4. Of the 23,824 cases, the average age was 25.04 (SD 5.78) years, ranging from 10 to 45 years.

Table 3.4: Mean and Median of Age (in Years) for Study Population

Variable	Number of Cases	Mean (years)	Median (years)	Standard deviation
Age	23,824	25.04	24	5.78

As shown in Table 3.5, the average age of cases who utilized the ED at least once during the prenatal period was 24.42 years (SD 5.50), about one year younger than women who did not use the ED (25.45 years (SD 5.93)). The median of those who utilized the ED at least once during the prenatal period was 23 years; two years younger than women who did not use the ED (25 years).

Table 3.5: Mean, Median and Range of Age (in Years) by ED Visit

	Cases With		All Cases (Age in years)
	No ED Visits (Age in years)	At Least One ED Visit (Age in years)	
Mean	25.45	24.42	25.04
Standard Deviation	5.93	5.50	5.78
Median	25	23	24
Minimum	10	12	10
Maximum	45	45	45
Number of Cases	14,175	9,649	23,824

### **Race/Ethnicity**

The subject’s race/ethnicity was a static variable captured from the supplemental client data file provided by UDMRP. Race codes were Black, Caucasian, Hispanic or Latina, Asian or Pacific Islander, and American Indian or Alaskan. Hispanic/Latina was not distinguished as a unique code for ethnicity.

The race variable was entered into the model as a series of dummy variables. Each dummy variable was coded “1” and “0”. To avoid perfect multicollinearity, a total of four dummy variables for race - Black, Hispanic or Latina, Asian/Pacific Islander, and American Indian or Alaskan - were entered into the model. Each of the four dummy variables representing race was used to compare with the reference race, Caucasian.

As shown in Table 3.6, of the 23,824 women in the analytic dataset, 37.4% (8,912 /23,824) were classified as Caucasian. Of those, 43.0% (3,833/8,912) utilized the ED at least once during the prenatal period. Thus, the combined total number of ED visits for Caucasian women was 8,960. Just over one-third of the sample population were classified as Black (8,719/23,824; 36.6%). Of those, 53.6% (4,677/8,719) utilized the ED at least once during the prenatal period. Thus, the

combined total number of ED visits for Black women was 11,445. Of the remaining cases (6,193/23,824; 25.9%), Hispanic or Latina accounted for (5,690/23,824; 23.9%), followed by Asian or Pacific Islander (463/23,824; 1.94%), and American Indian or Alaskan (40/23,824; 0.17%). ED utilization among women classified as Hispanic or Latina was the lowest among all race categories (1,012/5,690; 17.8%); the combined total number of ED visits for Hispanic or Latina was 2,247 visits. ED utilization among cases classified as Asian/Pacific Islanders and American Indian or Alaskan was 24.6% (114/463) and 32.5% (13/40), respectively, accounting for a total of 231 ED visits for these two groups.

Table 3.6: Race by ED Visit

Race	Cases With				Total Number of	
	No ED Visit	Percent	At Least One ED Visit	Percent	Cases	ED Visits
Asian and/or Pacific Islander	349	75.4%	114	24.6%	463	210
Black	4,042	46.4%	4,677	53.6%	8,719	11,445
Caucasian	5,079	57.0%	3,833	43.0%	8,912	8,960
Hispanic	4,678	82.2%	1,012	17.8%	5,690	2,247
American Indian and Alaskan	27	67.5%	13	32.5%	40	21
Total	14,175	59.5%	9,649	40.5%	23,824	22,883

#### **Presence of Disability/(ies)**

Using Medicaid eligibility pathway codes from the UDMRP supplemental file (also known as aid codes), women with at least one disability code present prior to delivery were flagged as having a disability. In this study, it was hypothesized that pregnant women with disabilities would use the ED more than pregnant women

without disabilities. Using Medicaid eligibility pathway codes, a total of 822 cases were classified as having a disability. Of those, 478 women (58.2%) visited the ED at least once during the prenatal period with a collective total of 1,559 ED visits (see Table 3.7).

Table 3.7: Number and Percent of Cases with a Disability by ED Visit

	Cases With				Total Number of	
	No ED visit	Percent	At Least One ED visit	Percent	Cases	ED Visits
Women with Disabilities	344	41.8%	478	58.2%	822	1,559

### **General Health Risk**

Two comorbidity measures were used in this study as independent variables, the first, the Charlson Comorbidity Index, was used to assess the underlying disease/disease burden of the study subjects unrelated to pregnancy. In this study, it was hypothesized that higher health risk scores were associated with ED utilization. A second comorbidity index used as an independent variable in this study, the Obstetric Comorbidity Index, was to assess maternal specific health/complications. Both indices use algorithms based on ICD-9 codes from both inpatient and outpatient medical claims and are described in detail in the sections below.

### **Charlson Comorbidity Index**

The Charlson Comorbidity Index was used as an independent variable measuring general underlying disease/disease burden for the study population. The Charlson Comorbidity Index consists of 17 diagnoses. Based on the adjusted risk of mortality or resource use, each diagnosis in the index is assigned a weight ranging

from 1 to 6 (Charlson et al., 2008; Doty et al., 1992). Subjects in this study were assigned a composite score based on the presence of ICD-9 diagnosis codes as defined by the index algorithm with scores ranging from 0 to 10. A score of 0 indicated no associated comorbidities; from that point, the higher the score, the greater burden of comorbidities.

The distribution of scores across the study population for the Charlson Comorbidity Index, regardless of ED use, is noted in Table 3.8; the scores for cases, by ED visit, are presented in Table 3.9.

Table 3.8: Charlson Comorbidity Index

Charlson Comorbidity Index	Number of Cases	Percent
0	19,985	83.9%
1	3,207	13.5%
2	379	1.6%
3	119	0.5%
4	79	0.3%
5	28	0.1%
6	8	0.03%
7	7	0.03%
8	8	0.03%
9	3	0.01%
10	1	0%
Total	23,824	100.0%

Table 3.9: Charlson Comorbidity Index Score by ED Visit

Charlson Comorbidity Index	Cases With				Total Number of	
	No ED Visit	<i>Percent</i>	At Least One ED Visit	<i>Percent</i>	Cases	ED Visits
0	12,650	89.2%	7,335	76.0%	19,985	16,117
1	1,258	8.9%	1,949	20.2%	3,207	5,646
2	174	1.2%	205	2.1%	379	565
3	36	0.3%	83	0.9%	119	307
4	40	0.3%	39	0.4%	79	111
5	7	0.1%	21	0.2%	28	71
6	3	0.02%	5	0.05%	8	13
7	1	0.01%	6	0.06%	7	33
8	4	0.03%	4	0.04%	8	13
9	1	0.01%	2	0.02%	3	7
10	1	0.01%	0		1	--
Total	14,175	100.0%	9,649	100.0%	23,824	22,883

### Obstetric Comorbidity Index

The Obstetric Comorbidity Index is a weighted algorithm that identifies maternal comorbidities. As described in the literature review, the index was developed especially for the obstetric population and takes into consideration the time-limited nature of pregnancy and the specific maternal related conditions that can impact maternal and fetal health, as well as health resource utilization (Bateman & Gagne, 2015). Using ICD-9 data from both inpatient and outpatient medical claims during the prenatal period, cases were assigned a composite score ranging from 0 to 13 based on a weighted index of 21 preexisting conditions or pregnancy-related conditions, and advanced maternal age. A score of 0 indicated no comorbidities; from that point, the higher the score the higher the obstetric health risks.

The distribution of scores across the study population for the Obstetric Comorbidity Index, regardless of ED use, is noted in Table 3.10; the scores for all cases, by ED visit, are presented in Table 3.11.

Table 3.10: Obstetric Comorbidity Index

Obstetric Comorbidity Index	Number of Cases	Percent
0	14,320	60.1%
1	4,318	18.1%
2	2,896	12.2%
3	1,098	4.6%
4	452	1.9%
5	397	1.7%
6	178	0.75%
7	94	0.39%
8	37	0.16%
9	18	0.08%
10	7	0.03%
11	5	0.02%
12	2	0.01%
13	2	0.01%
Total	23,824	100.0%

Table 3.11: Obstetric Comorbidity Index Score by ED Visit

Obstetric Comorbidity Index	Cases With				Total Number of	
	No ED Visit	Percent	At Least One ED Visit	Percent	Cases	ED Visits
0	9,258	65.3%	5,062	52.5%	14,320	11,030
1	2,531	17.9%	1,787	18.5%	4,318	44,08
2	1,452	10.2%	1,444	15.0%	2,896	3,452
3	459	3.2%	639	6.6%	1,098	1,796

Obstetric Comorbidity Index	Cases With				Total Number of	
	No ED		At Least One ED		Cases	ED Visits
	Visit	Percent	Visit	Percent		
4	184	1.3%	268	2.8%	452	865
5	162	1.1%	235	2.4%	397	693
6	68	0.5%	110	1.1%	178	298
7	39	0.3%	55	0.6%	94	158
8	10	0.1%	27	0.3%	37	131
9	5	0.04%	13	0.1%	18	18
10	5	0.04%	2	0.02%	7	14
11	2	0.01%	3	0.03%	5	8
12	0	--	2	0.02%	2	3
13	0	--	2	0.02%	2	9
Total	14,175	100%	9,649	100%	23,824	22,883

### Charlson Comorbidity and Obstetric Comorbidity Indices

Table 3.12 presents the average scores from the Charlson Comorbidity and the Obstetric Comorbidity indices by ED visit. The average Obstetric Comorbidity Index score for the total study population was calculated at 0.82. The average Obstetric Comorbidity Index score for women who utilized the ED at least once was higher compared to scores for women who did not use the ED ( $t(16,950) = -22.5, p < .001$ ). The average Charlson Comorbidity Index score for the total study population was calculated at 0.21. The average Charlson Comorbidity Index score for women who utilized the ED at least once was higher compared to scores for women did not use the ED,  $t(16,080.2) = -20.8, < .001$ .

Table 3.12: Average Score of Charlson Comorbidity Index and Obstetric Comorbidity Index by ED Visit

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Average Score for Comorbidity Index

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Type of Index	Cases with No ED visits	Cases with At Least One ED visit	All Cases	Two-Sample t-test with Unequal Variances
Obstetric	0.65	1.07	0.82	$t = -22.49^*$
Charlson	0.14	0.31	0.21	$t = -20.81^*$
Number of Cases	14,175	9,649	23,824	

*\*p < .001*

### **Duration of Medicaid Coverage**

As noted in the literature, not all women are enrolled in Medicaid at the time of conception and those that are enrolled during the prenatal period are covered for varying lengths of time. Without data on gestational age at delivery, length of time on Medicaid was defined as the consecutive number of days women were enrolled in the Medicaid program prior to delivery. Using the delivery date as an anchor, the length of time on Medicaid during the prenatal period was calculated by counting the number of days prior to delivery with no break in coverage longer than 33 days.

Using this definition, women were enrolled in Medicaid ranging from 1 day before delivery to more than 280 days before delivery. For analysis purposes, enrollment duration was categorized into four categories, as shown in Table 3.13. Medicaid eligibility duration was entered into the model as a series of dummy variables. To avoid perfect multicollinearity, three dummy variables representing Medicaid duration were entered into the model: (i) from 94 days to 1 day before delivery, (ii) from 187 days to 95 days before delivery, and (iii) at least 280 days before delivery. The remaining variable, 279 days to 188 days before delivery, was used as the reference for comparison with the three dummy variables. Use of dummy variables allowed comparison of the number of ED visits among women with partial and full Medicaid coverage during the prenatal period. In this study, it was

hypothesized that pregnant women with longer duration of Medicaid eligibility would be associated with more ED use.

Almost half of all cases (49.3%) were enrolled in Medicaid for at least 280 days prior to delivery; the remaining half had partial coverage ranging from 1 day to 279 days before delivery (see Table 3.13). Data revealed that the proportion of women with at least one ED visit was higher among those enrolled with longer Medicaid coverage (see Table 3.14).

Table 3.13: Length of Medicaid Coverage by ED Visit

Duration Enrolled in Medicaid	Cases With				Total Number of	
	No ED Visit	Percent	At Least One ED visit	Percent	Cases	Percent
>=280 days	5,562	39.2%	6,171	64.0%	11,733	49.3%
279-188 days	3,605	25.4%	2,318	24.0%	5,923	24.9%
187-95 days	3,008	21.2%	900	9.3%	3,908	16.4%
94-1 day	2,000	14.1%	260	2.7%	2,260	9.5%
Total	14,175	100%	9,649	100%	23,824	100%

Table 3.14: Average and Total Number of ED Visits by Medicaid Coverage

Duration Enrolled in Medicaid	Number of		Average Number of ED Visits	Standard Deviation
	ED Visits	Cases		
>=280 days	16,085	11,733	1.37	2.09
279-188 days	4,922	5,923	0.83	1.45
187-95 days	1,503	3,908	0.38	0.89
94-1 days	373	2,260	0.16	0.58

### **Inpatient Admission Within 24 Hours of ED Visit**

Inpatient admission within 24 hours of an ED visit was used as a proxy to define whether an ED visit was urgent or not. In this study, it was hypothesized that women with urgent ED visits would be associated with more ED use. The variable was defined as an inpatient claim within 24 hours of the ED visit date. Participants were categorized into two groups and entered into the model as a dummy variable: Medicaid recipients who were admitted to the inpatient setting within 24 hours of an ED visit were coded as 1; Medicaid recipients who visited the ED but were not admitted to the inpatient setting within 24 hours following their ED visit, and study participants who did not utilize the ED, were coded as 0.

Among the 23,824 Medicaid recipients, 5.5% of women (1,327/23,824) were admitted to an inpatient setting within 24 hours of the ED visit. The admission rate was 13.8% (1,327/9,649). Of those admitted, most were admitted only once (1,186/1,327; 89%). The average number of ED visits for those admitted once was 3.01; the number of ED visits for these women ranged from 1 to as high as 23. For those women who were admitted to the inpatient service twice after an ED visit (n=105), the average number of ED visits during the prenatal period for these women was 5.4. The remaining 36 women were admitted to the inpatient setting between 3 to 8 times (see Table 3.15).

Table 3.15: Average and Total Number of Inpatient Admissions within 24 Hours of an ED Visit

Number of Inpatient Admissions	Total Number of Cases		Average Number of ED	Standard Deviation	Total Number of	
	No	Yes			Cases	All ED Visits
None	22,497	n/a	0.8	1.53	22,497	18,428
1	0	1,186	3.0	2.61	1,186	3,577
2	0	105	5.4	3.45	105	565
3	0	27	8.3	4.88	27	225
4	0	3	8.7	2.08	3	26
5	0	3	12.3	6.66	3	37
6	0	2	7	1.41	2	14
8	0	1	11	n/a	1	11
Total	22,497	1,327	0.96	1.74	23,824	22,883

### Maternal Related ED Visits

Having a maternal related condition at the time of the ED visit was defined as cases who had a pregnancy-related diagnosis ICD-9 claim noted at the time of any ED visit. Maternal related conditions at the time of ED visits were specified in the model as a proxy for pregnant women using the ED for prenatal care. In this study, it was hypothesized that pregnant women who used ED visits for prenatal care would be associated with more ED use.

Participants were categorized into two groups and were entered into the model as a dummy variable: women with a pregnancy-related claim at any ED visit were coded as 1; women who did not visit the ED and women who visited the ED but did not have a pregnancy-related claim were coded as 0. See Appendix A for ICD-9 codes that included maternal related conditions.

As shown in Table 3.16, among the 9,649 women who visited the ED during the prenatal period, 78.7% (7,595/9,649) had at least one pregnancy-related claim. Of those with at least one pregnancy-related claim, the average and the total numbers of

ED visits were 2.62 and 19,894, respectively. Of those who did not visit the ED or visited and did not have a pregnancy-related claim (2,054/9,649; 21.3%), the average and the total numbers of ED visits was 0.18 and 2,989 visits, respectively.

Table 3.16: Maternal Related ED Visit

Maternal Related ED Visit	ED Visit		Average Number of ED visits	Standard Deviation	Total Number of	
	No ED Visit	At Least One ED Visit			Cases	ED Visits
No	14,175	2,054	0.18	0.60	16,229	2,989
Yes	0	7,595	2.62	2.17	7,595	19,894
Total	14,175	9,649	0.96	1.74	23,824	22,883

### 3.3 Statistical Methods for Count Data Outcomes

This section describes the statistical theory of count data as well as the theoretical model developed to predict the number of ED visits. Section 3.3.1 discusses the statistical theory. Section 3.3.2 offers justifications for using the Poisson regression model as opposed to other regression techniques. Section 3.3.3 discusses why the Negative Binomial regression model is the most appropriate for this dissertation.

#### 3.3.1 Poisson Distribution of Count Data

The key variable of interest for this study was ED visits by pregnant women enrolled in Medicaid. ED visit counts by case ranged from zero or no visits to 25 visits. The one outlier case which had 83 ED visits was collapsed to 25 visits. Mathematically, the dependent variable in this study is a count variable (number of ED visits). It is a non-negative integer or discrete data and follows a Poisson

distribution. See Figure 3.1 for the distribution of ED visits. Due to the shape of the distribution on the number of ED visits and the theoretical explanation presented in Section 3.3.2, the Poisson regression was determined to be the most appropriate model for estimating the count outcome in this study.

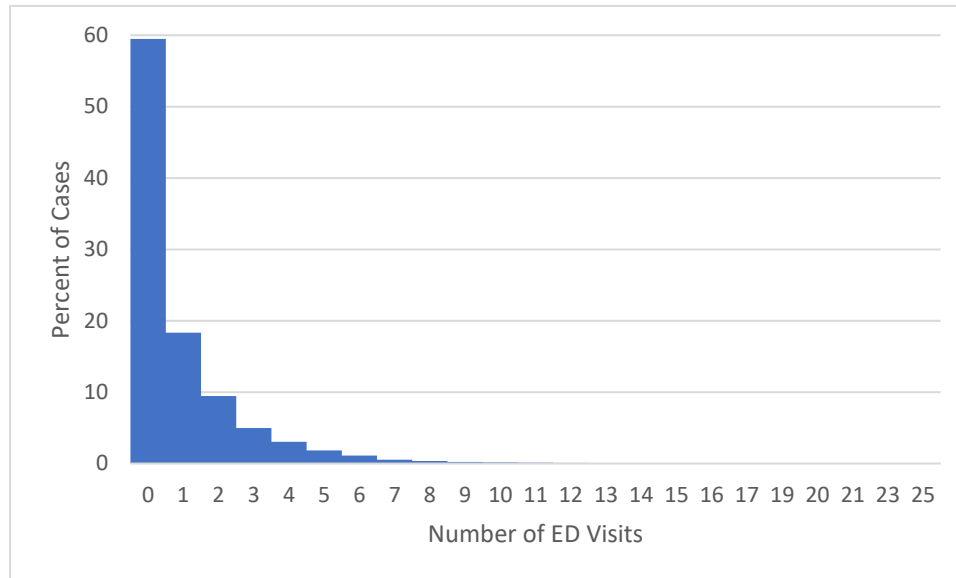


Figure 3.1: Number of ED Visits by Percent of Cases

Theoretically, a random variable of  $y$  is said to have a Poisson distribution with parameter of  $\mu$  if  $y$  is equal to an integer value:  $y = 0, 1, 2, 3$ , etc. In this study,  $y$  is equal to the number of ED visits, that is, a non-negative integer value of  $0, 1, 2, 3, \dots$  etc. as noted in the above paragraph. Thus, the probability of the count on number of times women utilized the ED during the 280 days prior to delivery has a Poisson distribution; the Poisson probability distribution function is defined mathematically in Equations 3.1 and 3.2 (Agresti, 2019; Long, 2014) as follows:

$$Pr(y|\mu) = \frac{e^{-\mu}\mu^y}{y!} \dots \dots \dots (3.1)$$

$$Pr(y|\mu) = \frac{\exp(-\mu)\mu^y}{y!} \dots \dots \dots (3.2)$$

Under the Poisson distribution, the predicted probability of the count (or ED visits), at the given value of  $\mu$ , can be calculated using Equation 3.2. As shown in Table 3.3, the average number (or  $\mu$ ) of ED visits over the 280-day period prior to delivery was estimated at 0.96. The calculations for the probabilities of  $y = 0, 1, 2, 3, 4$  in a 280-day interval are shown in Table 3.17.

Table 3.17: Predicted Probability of the Number of ED Visits (0 to 4 Visits) for  $\mu = 0.96$

# of visits	Pr(y = # of events  $\mu$ )	Predicted Probability
0	$\text{Exp}(-\mu)/0!$	$[(e^{-.96})(.96)]/0!=0.382$ (Probability of no visit in 280 days is 0.382)
1	$\text{Exp}(-\mu)\mu/1!$	$[(e^{-.96})(.96^1)]/1!=0.367$ (Probability of one visit in 280 days is 0.367)
2	$\text{Exp}(-\mu)\mu^2/2!$	$[(e^{-.96})(.96^2)]/2!=0.176$ (Probability of two visits in 280 days is 0.176)
3	$\text{Exp}(-\mu)\mu^3/3!$	$[(e^{-.96})(.96^3)]/3!=0.056$ (Probability of three visits in 280 days is 0.056)
4	$\text{Exp}(-\mu)\mu^4/4!$	$[(e^{-.96})(.96^4)]/4!=0.013$ (Probability of four visits in 280 days is 0.013)

Note: The predicted counts are calculated using Equation 3.2

The Poisson distribution is based on the following properties as described by Long (1997):

- The shape of the distribution will shift to the right as  $\mu$  increases and approximates a normal distribution. The parameter of  $\mu$  is known as the rate since it is the expected number of times that an event occurs per unit of time, or it can be thought of as the mean of an expected count (Long, 1997).



important to note that count variables follow a Poisson distribution, whereas continuous variables that are used as the dependent variable in a typical linear regression model can take on any value and follow a normal distribution.

To correct for the deficiency of the linear regression model, the Poisson regression model is preferred over the linear regression model because the probability of the count outcome is determined by Poisson distribution and the mean of the distribution is a function of the independent variables (see Equation 3.3). Since the count cannot be negative, an exponential of  $x\beta$  forces the expected count to be positive. The expected value of  $y$  for a given  $x$  is shown in Equation 3.4.

$$\mu_i = E(y_i|x_i) = \exp(x_i\beta) \dots \dots \dots (3.4)$$

In Equation 3.4, the regression coefficient  $\beta_i$  represents the expected change in the log of the mean per unit change in the predictor  $x_i$ . As noted in the equation, increasing  $x_i$  by 1 unit is associated with an increase of  $\beta_i$  in the log of the mean. An exponentiated regression coefficient  $\exp(\beta_i)$  represents the multiplicative effect of the  $i^{\text{th}}$  predictor on the mean. Thus, increasing  $x_i$  by 1 unit multiplies the mean by a factor of  $\exp(\beta_i)$  (Long, 1997; Long & Freese, 2014).

### **3.3.3 Use of the Negative Binomial Regression Model**

As noted in Section 3.3.1, a key assumption of the Poisson regression model is that the conditional mean of the count outcome is equal to the conditional variance. However, in practice, count data tends to be over-dispersed and the variance tends to be greater than the mean. As discussed in Section 3.2.1, the average number of ED visits was 0.96 and the variance was 3.03 which indicates that the count data of ED visits is likely to be over-dispersed. When there is overdispersion, the estimated number of ED visits from the Poisson regression model are inefficient with the

standard errors lower, that is biased downward. In turn, results yield inflated z-values given the relationship between standard error and the coefficient to calculate the z values (coefficient/standard error). This is true even if the model is specified with the correct variables (Long, 1997). If the Poisson regression model is used when there is overdispersion in the count data, there is a risk that the independent variables will mistakenly be considered significant when they are not. Therefore, testing for overdispersion before using the Poisson regression model is critical (Long & Freese, 2014). If overdispersion is confirmed, a Negative Binomial regression model must be employed, since the model allows the variance to be greater than the mean.

Considering that the variance is greater than the mean due to overdispersion, the Negative Binomial regression model adds a dispersion parameter (or  $\alpha$ ) that allows the conditional variance of  $y$  to be greater than the mean. Thus,

$$var(Y) = \mu(1 + \alpha \mu) \dots \dots \dots (3.5)$$

When the dispersion parameter is 0, or  $\alpha = 0$ , there is no unobserved heterogeneity (the outcome variable is not over-dispersed), thus, the mean is equal to the variance and the Poisson regression model can be applied. However, when  $\alpha > 0$ , the variance is larger than the mean and the Negative Binomial regression model should be used. Since the variance is larger than the mean, an error term is added into the Negative Binomial regression model and  $\mu$  is replace with a random variable  $\tilde{\mu}$ .

$$\tilde{\mu} = exp\{x_i'\beta + \varepsilon_i\} \dots \dots \dots (3.6)$$

In Equation 3.6,  $\varepsilon_i$  is a random error that is assumed to be uncorrelated with  $x$ . In the Poisson regression model, variation in  $\mu$  is introduced through observed heterogeneity of the independent variables. Different values of  $x$  results in different values of  $\mu$ , but all individuals with the same  $x$  have the same  $\mu$  (Long, 1997). In

Negative Binomial regression model, variation in  $\tilde{\mu}$  is due both to variation in  $x$  among individuals and to unobserved heterogeneity introduced by  $\varepsilon$ . For a given combination of values for the independent variables there is a distribution of  $\tilde{\mu}'s$  rather than a single  $\mu$  (Long, 1997) as defined below.

$$\tilde{\mu} = \exp(x_i' \beta) \exp(\varepsilon_i) \dots \dots \dots (3.7)$$

### 3.4 Justification and Model Specification

This section discusses the justification and model specification using the Negative Binomial regression analyses. Based on the empirical data for this dissertation, Section 3.4.1 provides justification for including independent variables in the model to predict the number of ED visits. Section 3.4.2 presents the regression model. Section 3.4.3 presents the statistical test for the model.

#### 3.4.1 Justification for Independent Variables

Justification for inclusion of independent variables used to predict the number of ED visits discussed in this section was primarily based on descriptive statistical analysis that was conducted by exploring the association between the number of ED visits and each independent variable. Although the dependent variable used in this dissertation was the number of ED visits, in this section, ED visits were collapsed to no visit and at least one visit. It was used as a proxy for the numbers of ED visits and to demonstrate the association with each independent variable used in the model.

##### **Age, Race/Ethnicity, and Presence of a Disability**

The age of the pregnant women enrolled in the study were included in the model as one of the three demographic factors used to determine the number of ED visit. Pearson's correlation coefficient between the number of ED visits and age

showed low correlation ( $r(23,822) = -0.06, p < .001$ ). Since the correlation coefficient is negative, it is expected that younger women would be more likely to utilize the ED than older women.

As shown in Figure 3.2, with age categorized into groups, the proportion of women visiting the ED at least once was highest among those aged younger than 19. As age increased, the proportion of pregnant women visiting the ED at least once decreased.

As shown in Table 3.18, the Pearson Chi-squared test of independence between age and a dichotomous ED visit variable showed that there was a significant relationship between the two variables ( $\chi^2(6, N=23,824) = 180.89, p\text{-value} < .001$ ). In addition, as captured in the right-hand columns of Table 3.18, the findings reinforce that as age increases the average number of ED visits decreases. One-way ANOVA showed that the average number of ED visits were statistically significantly different among the seven age groups, ( $F(6, 9642) = 5.81, p < .001$ ).

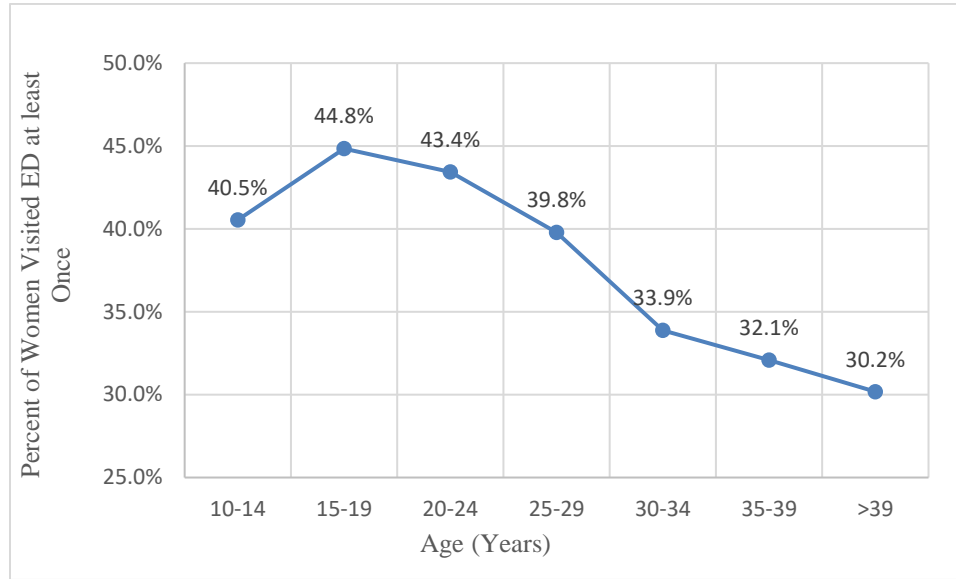


Figure 3.2: Percent of Women with at Least One ED Visit by Age Groups

Table 3.18: Age by ED Visit and Average Number of ED Visits by Age

Age (in Years)	Cases with No ED Visit	Cases with At Least One ED visits	Total Number of Cases	Average Number of ED Visits
10 to 14	44	30	74	2.3
<i>Percent</i>	59.5%	40.5%	100%	<i>N=30</i>
15 to 19	2,211	1,797	4,008	2.2
<i>Percent</i>	55.2%	44.8%	100%	<i>N=1,797</i>
20 to 24	4,763	3,657	8,420	2.5
<i>Percent</i>	56.6%	43.4%	100%	<i>N=3,657</i>
25 to 29	3,761	2,485	6,246	2.4
<i>Percent</i>	60.2%	39.8%	100%	<i>N=2,485</i>
30 to 34	2,162	1,108	3,270	2.3
<i>Percent</i>	66.1%	33.9%	100%	<i>N=1,108</i>
35 to 39	961	454	1,415	2.1
<i>Percent</i>	67.9%	32.1%	100%	<i>N=454</i>
> 39	273	118	391	2.0
<i>Percent</i>	69.8%	30.2%	100%	<i>N=118</i>
Total	14,175	9,649	23,824	2.4
<i>Percent</i>	59.5%	40.5%	100%	<i>N=9,649</i>

$\chi^2 (6, N=23,824) = 180.89, p\text{-value} < .001$ )

$F (6, 9642) = 5.81, p < .001$

Most women in the study population were Caucasian (37.4%) and Black (36.6%), followed by Hispanic or Latina (23.9%), Asian/Pacific Islanders (1.9%) and American Indian and Alaskan (<1%). As shown in Figure 3.3, ED use varied among race/ethnic groups. Approximately half of all Black women (53.6%) visited the ED at least once, followed by Caucasians (43.0%). Hispanic or Latina women visited the ED least across all race/ethnicity groups.

As shown in Table 3.19, the Chi-Squared test of independence between race/ethnicity and a dichotomous ED visit variable showed that there was a significant relationship between the two variables, ( $\chi^2 (4, N=23,824) = 1900.00, p\text{-value} < .001$ ). In addition, as captured in the right-hand columns of Table 3.19, the findings reinforced that Black and Caucasian women made the most visits, averaging 2.4 and 2.3 visits, respectively. The average numbers of ED visits among Hispanic or Latina, Asian/Pacific Islanders, and American Indian and Alaskan women were estimated at 2.2, 1.8, and 1.6, respectively. One-way ANOVA showed that the average number of ED visits among women with different race/ethnic background were statistically significant, ( $F (4, 9644) = 5.67, p < .001$ ).

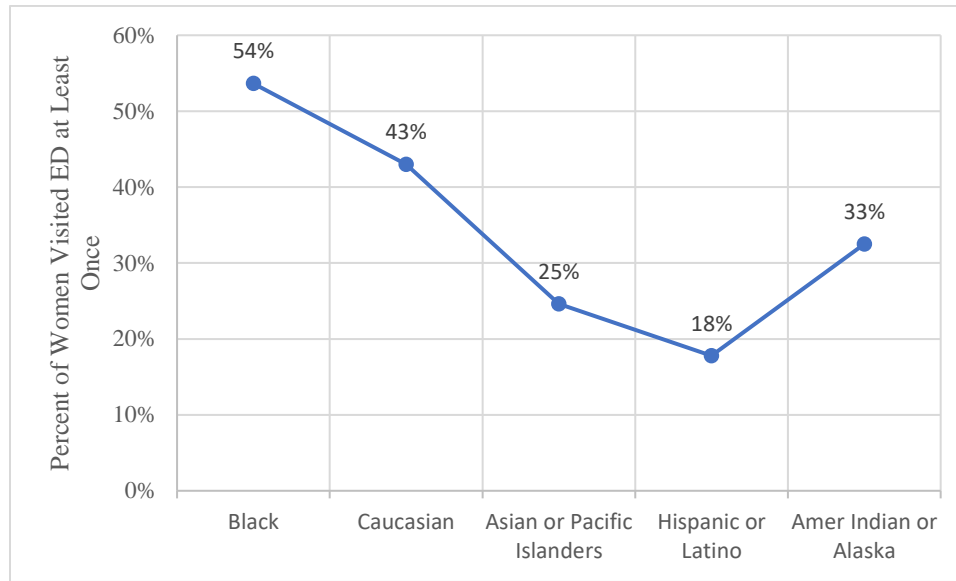


Figure 3.3: Percent of Women with at Least One ED Visit by Race/Ethnicity

Table 3.19: Race/Ethnicity by ED Visit and Average Number of ED Visits by Race/Ethnicity

Race/Ethnicity	Cases with No ED Visit	Cases with At Least One ED Visits	Total Number of Cases	Average Number of ED Visits
Black	4,042	4,677	8,719	2.4
<i>Percent</i>	<i>46.4%</i>	<i>53.6%</i>	<i>100%</i>	<i>N=4,677</i>
Caucasian	5,079	3,833	8,912	2.3
<i>Percent</i>	<i>57.0%</i>	<i>43.0%</i>	<i>100%</i>	<i>N=3,833</i>
Hispanic or Latina	4,678	1,012	5,690	2.2
<i>Percent</i>	<i>82.2%</i>	<i>17.8%</i>	<i>100%</i>	<i>N=1,012</i>
Asian and Pacific Islanders	349	114	463	1.8
<i>Percent</i>	<i>75.4%</i>	<i>24.6%</i>	<i>100%</i>	<i>N=114</i>
American Indian and Alaskan	27	13	40	1.6
<i>Percent</i>	<i>67.5%</i>	<i>32.5%</i>	<i>100%</i>	<i>N=13</i>

Total	14,175	9,649	23,824	2.4
Percent	59.5%	40.5%		<i>N</i> =9,649

$\chi^2 (4, N=23,824) = 1900.00, p\text{-value} < .001;$        $F (4, 9644) = 5.67, p < .001$

The last demographic variable in the model was the presence of disabilities. As shown in Table 3.20, of women with disabilities, 58.2% visited the ED at least once, whereas 39.9% of women without disabilities visited the ED at least once. The Pearson Chi-squared test of independence between presence of disability and a dichotomous ED visit variable showed that there was a significant relationship between the two variables, ( $\chi^2 (1, N=23,824) = 110.06, p\text{-value} < .001$ ). In addition, as captured in the right-hand columns of Table 3.20, the findings reinforce those women with disabilities had on average 3.3 ED visits compared to 2.3 ED visits for those without disabilities. The average number of ED visits was significantly higher for women with disabilities than women without disabilities using a two-sample t-test with unequal variance ( $t (501.39) = -7.14, p < .001$ ).

Table 3.20: Women with Disability(ies) by ED Visit and Average Number of ED Visits by Women with Disability

Pregnant Women with Disability	Cases with No ED Visit	Cases with At Least One ED Visits	Total Number of Cases	Average Number of ED Visits
Yes	344	478	822	3.3
Percent	41.9%	58.2%	100%	<i>N</i> =478
No	13,831	9,171	23,002	2.3
Percent	60.1%	39.9%	100%	<i>N</i> =9,171
Total	14,175	9,649	23,824	2.4
Percent	59.5%	40.5%	100%	<i>N</i> =9,649

$\chi^2 (1, N=23,824) = 110.06, p\text{-value} < .001;$        $t (501.39) = -7.14, p < .001$

### **Charlson Comorbidity Index and Obstetric Comorbidity Index**

Two comorbidity indices (the Charlson Comorbidity Index and the Obstetric Comorbidity Index) were entered into the model. Results of the Pearson correlation coefficient between these two health risk indices indicated low correlation ( $r(23,824) = 0.18, p < .001$ ).

Pearson's correlation coefficient between the number of ED visits and the Charlson Comorbidity Index scores also showed low correlation ( $r(23,822) = 0.17, p < .001$ ). Since the correlation coefficient is positive, it is expected that women who have a higher Charlson Comorbidity Index score would be more likely to utilize the ED than women who had lower scores. As shown in Figure 3.4, among pregnant women with a 0 score, 36.7% had at least one visit. Among pregnant women with a score of 1 or 2 on the Charlson Comorbidity Index, the proportion who visited the ED at least once was 60.8% and 54.1%, respectively. The findings demonstrated that among women whose score was higher than 2, the proportion who visited the ED continued to trend upwards.

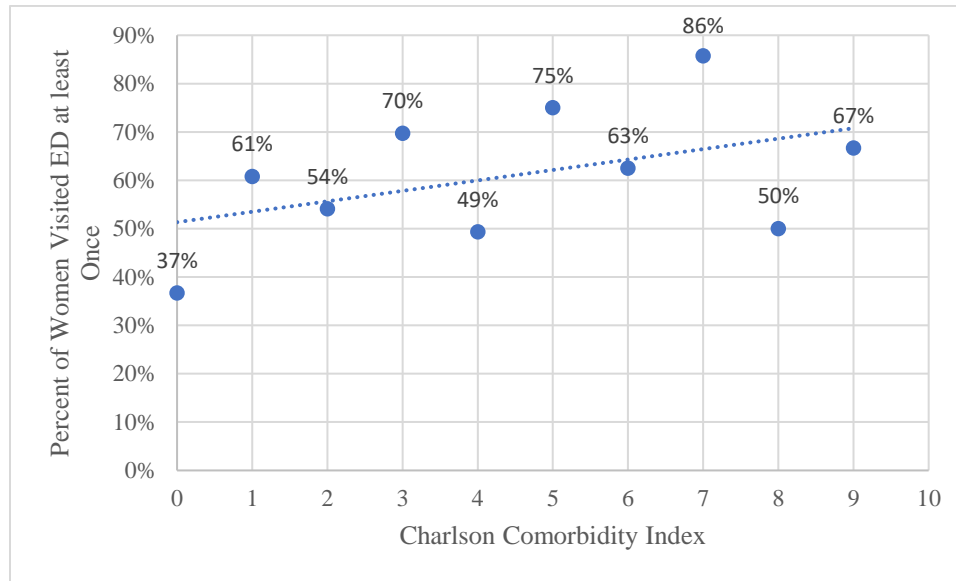


Figure 3.4: Percent of Women with at Least One ED Visit by Charlson Comorbidity Index Score

The Chi-squared test of independence between Charlson Comorbidity Index scores and the dichotomous ED visit variable revealed that there was a significant relationship between the two variables ( $\chi^2 (10, N=23,824) = 763.65, p\text{-value} < .001$ ). In addition, the average number of ED visits captured in the right-hand columns of Table 3.21, reinforces that woman with higher Charlson Comorbidity Index scores used the ED more. One-way ANOVA showed that the average number of ED visits among women with different scores were statistically significant,  $F (9, 9639) = 28.44, p < .001$ .

Table 3.21: Charlson Comorbidity Index Score by ED Visit and Average Number of ED Visits by Score of Charlson Comorbidity Index

Cases with At Least	Number of ED Visits
---------------------	---------------------

Charlson Comorbidity Index Score	Cases with No ED Visit	One ED Visits	Total Number of Cases	Average	Total
Zero	12,650	7,335	19,985	2.2	16,117
<i>Percent</i>	63.3%	36.7%	100%	<i>N=7,335</i>	
One	1,258	1,949	3,207	2.9	5,646
<i>Percent</i>	39.2%	60.8%	100%	<i>N=1,949</i>	
Two	174	205	379	2.8	565
<i>Percent</i>	45.9%	54.1%	100%	<i>N=205</i>	
Three	36	83	119	3.7	307
<i>Percent</i>	30.2%	69.8%	100%	<i>N=83</i>	
Four	40	39	79	2.8	111
<i>Percent</i>	50.6%	49.4%	100%	<i>N=39</i>	
Five	7	21	28	3.4	71
<i>Percent</i>	25.0%	75.0%	100%	<i>N=21</i>	
Six	3	5	8	2.6	13
<i>Percent</i>	37.5%	62.5%	100%	<i>N=5</i>	
Seven	1	6	7	5.5	33
<i>Percent</i>	14.3%	85.7%	100%	<i>N=6</i>	
Eight	4	4	8	3.3	13
<i>Percent</i>	50.0%	50.0%	100%	<i>N=4</i>	
Nine	1	2	3	3.5	7
<i>Percent</i>	33.3%	66.7%	100%	<i>N=2</i>	
Ten	1	--	1	--	--
<i>Percent</i>	100%	--	100%	--	--
Total	14,175	9,649	23,824	2.4	22,883
<i>Percent</i>	59.5	40.5	100%	<i>N=9,649</i>	

$\chi^2$  (10, N=23,824) = 763.65, p-value <.001) ; F (9, 9639) = 28.44, p < .001

The second health index, the Obstetric Comorbidity Index, was developed to measure the health risks specific to pregnancy. Pearson's correlation coefficient between the number of ED visits and the Obstetric Comorbidity Index scores showed low correlation ( $r(23,822) = 0.17, p < .001$ ). The correlation coefficient was positive; thus, it is expected that women who have a higher Obstetric Comorbidity Index score would be more likely to utilize the ED than women who had lower scores.

As shown in Figure 3.5, among pregnant women with a 0 score, 35.4% had at least one visit. Among pregnant women with a score of 1 or 2 on the Obstetric

Comorbidity Index, the proportion who visited the ED was 41.4% and 49.9%, respectively. The findings demonstrate that among women whose score was higher than 2, the proportion who visited the ED continued to trend upwards.

The Pearson Chi-squared test of independence between the Obstetric Comorbidity Index scores and the dichotomous ED visit variable, revealed that there was a significant relationship between the two variables ( $\chi^2$  (13, N=23,824) = 607.84, p-value <.001). In addition, the average number of ED visits captured in the right-hand columns of Table 3.22, reinforces that those women with higher Obstetric Comorbidity Index scores used the ED more. One-way ANOVA showed that the average number of ED visits among women with different scores were statistically significant,  $F$  (13, 9635) = 16.35,  $p$  < .001.

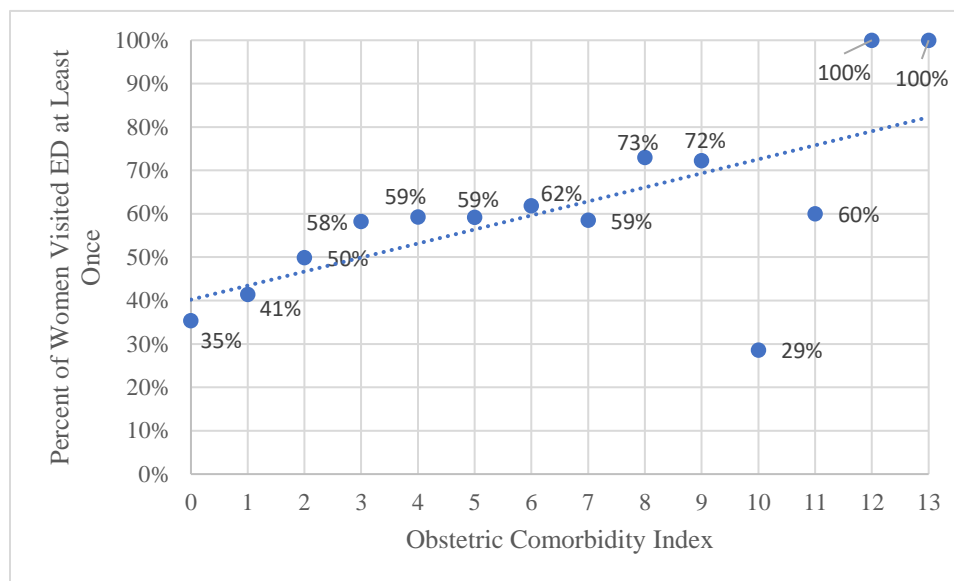


Figure 3.5: Percent of Pregnant Women with at Least One ED Visit by Obstetric Comorbidity Index

Table 3.22: Obstetric Comorbidity Index Score by ED Visit and Average Number of ED Visits by Score of Obstetric Comorbidity Index

Obstetric Comorbidity Index	Cases with No ED Visit	Cases with at Least One ED Visits	Total Number of Cases	Number of ED Visits	
				Average	Total
Zero	9,258	5,062	14,320	2.2	11,030
<i>Percent</i>	64.7%	35.4%	100%	<i>N=5,062</i>	
One	2,531	1,787	4,318	2.5	4,408
<i>Percent</i>	58.6%	41.4%	100%	<i>N=1,787</i>	
Two	1,452	1,444	2,896	2.4	3,452
<i>Percent</i>	50.1%	49.9%	100%	<i>N=1,444</i>	
Three	459	639	1,098	2.8	1,796
<i>Percent</i>	41.8%	58.2%	100%	<i>N=639</i>	
Four	184	268	452	3.2	865
<i>Percent</i>	40.7%	59.3%	100%	<i>N=268</i>	
Five	162	235	297	2.9	693
<i>Percent</i>	40.8%	59.2%	100%	<i>N=235</i>	
Six	68	110	178	2.7	298
<i>Percent</i>	38.2%	61.8%	100%	<i>N=110</i>	
Seven	39	55	94	2.9	158
<i>Percent</i>	41.5%	58.5%	100%	<i>N=55</i>	
Eight	10	27	37	4.9	131
<i>Percent</i>	27.0%	73.0%	100%	<i>N=27</i>	
Nine	5	13	18	1.4	18
<i>Percent</i>	27.8%	72.2%	100%	<i>N=13</i>	
Ten	5	2	7	7.0	14
<i>Percent</i>	71.4%	28.6%	100%	<i>N=2</i>	
Eleven	2	3	5	2.7	8
<i>Percent</i>	40.0%	60.0%	100%	<i>N=3</i>	
Twelve	--	2	2	1.5	3
<i>Percent</i>	--	100%	100%	<i>N=2</i>	
Thirteen	--	2	2	4.5	9
<i>Percent</i>	--	100%	100%	<i>N=2</i>	
Total	14,175	9,649	23,824	2.4	22,883
<i>Percent</i>	59.5	40.5	100%	<i>N=9,649</i>	

$\chi^2$  (13, N=23,824) = 607.84, p-value <.001)

F (13, 9635) = 16.35, p < .001

### **Duration of Medicaid Coverage**

The duration of Medicaid coverage was categorized into four groups. As shown in Figure 3.6, the proportion of pregnant women visiting the ED at least once was highest among those with the longest coverage. As length of coverage decreased, the proportion of pregnant women visiting the ED at least once also decreased.

The Pearson Chi-squared test of independence between Medicaid coverage duration and a dichotomous ED visit variable showed that there was a significant relationship between the two variables  $\chi^2 (3, N=23,824) = 2000.00, p\text{-value} < .001$ ). As shown in the right-hand columns of Table 3.23, the average number of ED visits were higher among pregnant women with longer duration of Medicaid coverage. One-way ANOVA confirmed that the average number of ED visits was statistically significantly different among pregnant women with different durations of Medicaid coverage  $F(3, 9645) = 95.82, p < .001$ .

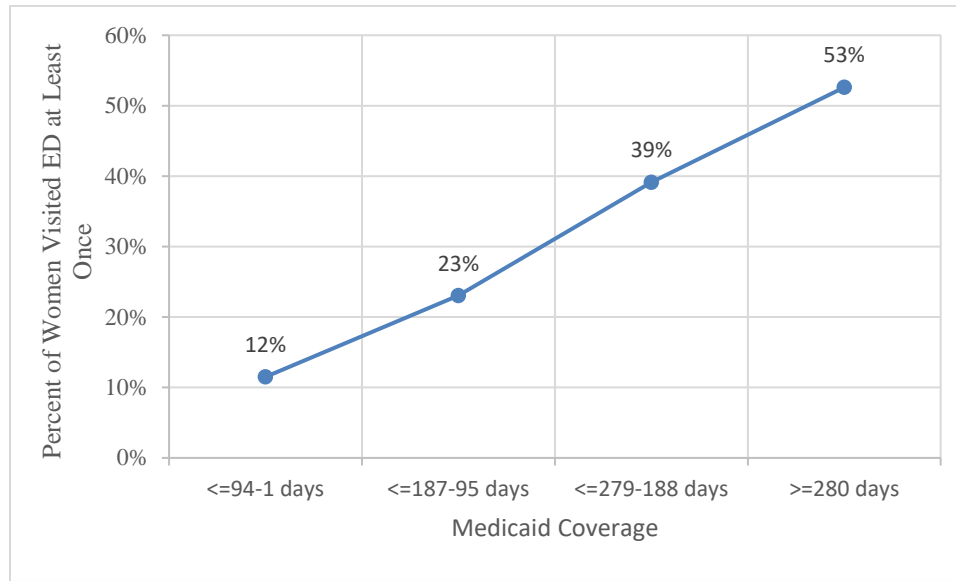


Figure 3.6: Percent of Pregnant Women with at Least One ED Visit by Duration of Medicaid Coverage

Table 3.23: Duration of Medicaid Coverage by ED Visit and Average Number of ED Visits by Duration of Medicaid Coverage

Duration of Medicaid Coverage	Cases with No ED Visit	Cases with at Least One ED visits	Total Number of Cases	Number of ED Visits	
				Average	Total
>=280 days	5,562	6,171	11,733	2.6	16,805
<i>Percent</i>	<i>47.4%</i>	<i>52.6%</i>	<i>100%</i>	<i>N=6,171</i>	
279-188 days	3,605	2,318	5,923	2.1	4,922
<i>Percent</i>	<i>60.86%</i>	<i>39.14%</i>	<i>100%</i>	<i>N=2,318</i>	
187-95 days	3,008	900	3,908	1.7	1,503
<i>Percent</i>	<i>76.97%</i>	<i>23.03%</i>	<i>100%</i>	<i>N=900</i>	
94-1 days	2,000	260	2,260	1.4	373
<i>Percent</i>	<i>88.5%</i>	<i>11.5%</i>	<i>100%</i>	<i>N=260</i>	
Total	14,175	9,649	23,824	2.4	22,883
<i>Percent</i>	<i>59.5%</i>	<i>40.5%</i>	<i>100%</i>	<i>N=9,649</i>	

$\chi^2$  (3, N=23,824) = 2000.00, p-value <.001)

F(3, 9645) = 95.82, p < .001

### Inpatient Admission Within 24 Hours of ED Visit

Among the 9,649 pregnant women who visited the ED, a total of 1,327 (13.8%) were admitted to inpatient care within 24 hours, for a collective total of 1,524 inpatient admissions. The Pearson's correlation coefficient between the number of ED visits (0 to 25) and the number of inpatient admissions (0 to 8) showed moderate correlation ( $r(23822) = 0.36, p < .001$ ).

As shown in the right-hand columns of Table 3.24, the average number of ED visits was 3.4 among those admitted to the inpatient setting within 24 hours versus 2.2 among those who were not admitted. The two-sample t-test with unequal variance showed that the average number of ED visits between the two groups of women was statistically significantly different,  $t(1483.42) = -13.62, p < .001$ . The Chi-squared test of independence was not used to test the association between the variables representing ED visit and inpatient admission because there was an empty cell representing women who did not visit the ED.

Table 3.24: Inpatient Admission by ED Visit and Average Number of ED Visits by Inpatient Admission

Inpatient Admission 24 hrs. After ED Visit	Cases with No ED Visit	Cases with At Least One ED Visits	Total Number of Cases	Number of ED Visits	
				Average	Total
No admission	14,175	8,322	22,497	2.2	18,428
<i>Percent</i>	<i>63.0%</i>	<i>37.0%</i>	<i>100%</i>	<i>N=8,322</i>	
Admission	0	1,327	1,327	3.4	4,455
<i>Percent</i>	--	<i>100%</i>	<i>100%</i>	<i>N=1,327</i>	
Total	14,175	9,649	23,824	2.4	22,883
<i>Percent</i>	<i>59.5%</i>	<i>40.5%</i>	<i>100%</i>	<i>N=9,649</i>	

$t(1483.42) = -13.62, p < .001$

### Maternal Related ED Visit

Of the 9,649 pregnant women who visited the ED at least once, 7,595 women (78.7%) visited the ED for maternal related conditions. As shown in the right-hand columns of Table 3.25, the average number of ED visits was 2.6 among those with a maternal related condition versus 1.5 among those without a maternal related condition. The two-sample t-test with unequal variance showed that the average number of ED visits between the two group of women was statistically significantly different ( $t(7369.43, 9,649) = -35.07, p < .001$ ). The Chi squared test of independence was not used to assess the association between the variables representing ED visit and maternal related conditions because there was an empty cell representing women who did not visit the ED.

Table 3.25: Maternal Related ED Visit by ED Visit and Average Number of ED Visits by Maternal Related ED Visit

Maternal Related ED Visit	Cases with No ED Visit	Cases with At Least One ED Visits	Total Number of Cases	Number of ED Visits	
				Average	Total
No	14,175	2,054	16,229	1.5	2,989
<i>Percent</i>	87.3%	12.7%	100%	<i>N=2,054</i>	
Yes	0	7,595	7,595	2.6	19,894
<i>Percent</i>	--	100%	100%	<i>N=7,595</i>	
Total	14,175	9,649	23,824	2.4	22,883
<i>Percent</i>	59.5	40.5	100%	<i>N=9,649</i>	

$t(7369.43) = -35.07, p < .001$

### 3.4.2 Model Specification for Predicting Emergency Department Utilization

In this dissertation, the model used to predict ED visits was specified by eight independent variables. The independent (predictor) variables in the model were (i)

age, (ii) race/ethnicity, (iii) presence of a disability (iv) Charlson Comorbidity Index, (v) Obstetric Comorbidity Index, (vi) duration of Medicaid coverage during the prenatal period prior to delivery, (vii) whether the ED visit resulted in hospitalization, that is whether it was urgent or not, and (viii) whether the ED visit was a maternal related visit. The two categorical variables representing race/ethnicity and Medicaid coverage were entered into the model as a series of dummy variables. Based on Equations 3.4 and 3.7, the Poisson and Negative Binomial regression for the dependent variable and eight independent variables for this study are applied in Equation 3.8 and 3.9, respectively.

Poisson Regression Model

$$\mu = \exp(\beta_0 + \beta_1x_1 + \dots + \beta_3x_3 + \dots + \beta_8x_8) \dots \dots \dots (3.8)$$

Negative Binomial Regression Model

$$\tilde{\mu} = \exp(\beta_0 + \beta_1x_1 + \dots + \beta_3x_3 + \dots + \beta_8x_8 + \varepsilon_9) \dots \dots \dots (3.9)$$

where:

- $\mu, \tilde{\mu}$  represents the count of emergency department (ED) utilization (visits).
- $x_1$  represents age.
- $x_2$  represents race/ethnicity (four dummy variables).
- $x_3$  represents the Charlson Comorbidity Index.
- $x_4$  represents the Obstetric Comorbidity Index.
- $x_5$  represents duration of Medicaid coverage (three dummy variables).
- $x_6$  represents Medicaid recipients with disability.
- $x_7$  represents inpatient utilization within 24 hours of ED visit.
- $x_8$  represents maternal related ED visit.

- $\varepsilon_9$  represents random error to account for unobserved heterogeneity.

As shown in Section 3.2.1, the ED visit count data are highly dispersed, ranging from 0 to 25 visits. Thus, conditional variance is more than three times greater than the conditional mean (variance = 3.03; mean = 0.96). Aside from examining the mean and the variance of the number of ED visits, the first step in examining for overdispersion was to review the standard errors between the Poisson and the Negative Binomial regression model results. If overdispersion is suspected and not accounted for, overdispersion will result in lower standard errors and in turn leads to misinterpretation of the output and results. As shown in Table 3.26, the standard errors of the coefficients of the Poisson regression model were consistently lower than those of the Negative Binomial regression model, which in turn yielded spuriously large z-values (z-values are not shown in Table 3.26).

As discussed in Section 3.3.3, the Negative Binomial regression model has the same mean structure as the Poisson regression, but it includes an overdispersion parameter (or  $\alpha$ ) in the model to test for over dispersion. The dispersion parameter  $\ln(\alpha)$  and  $\alpha$  included in the Negative Binomial regression model had coefficients of -1.705 and 0.182, respectively (see Table 3.26). To test for overdispersion the hypothesis for  $\alpha = 0$  must be set. The hypothesis testing for  $\alpha$  (the one-tailed z-test,  $H_0: \alpha = 0$ ) revealed that  $\alpha$  was greater than zero and statistically significant at  $p < .001$ , thus leading to a rejection of the hypothesis that  $\alpha$  is equal to 0. Given the dispersion parameter,  $\alpha$  was significantly greater than zero, suggesting that the count data for ED visits was over-dispersed. This confirms that the Negative Binomial regression should be used to estimate the model.

In addition, the results of the Likelihood ratio test of alpha also confirmed overdispersion of the ED count data. When comparing the log likelihood estimates between the Poisson and the Negative Binomial regression models, the likelihood ratio test of alpha showed  $G^2 = 881.654$ , which was statistically significant  $p < .001$ .

The Likelihood ratio test of alpha was computed as follows:

$$G^2 = 2(\ln\text{LNBRM} - \ln\text{LPRM})$$

$$G^2 = 2[-22269.759 - (-22710.586)] = 881.654$$

where:

$\ln\text{LNBRM}$  is the log likelihood estimate of the Negative Binomial Regression Model, and

$\ln\text{LPRM}$  is the log likelihood estimate of the Poisson Regression model.

In summary, the statistical test of the dispersion parameter in the Negative Binomial regression model and the likelihood ratio test of alpha confirmed that the count data for ED utilization was over-dispersed. Given these findings, the Negative Binomial regression model was preferred to the Poisson regression model.

Table 3.26: Comparison of Poisson and Negative Binomial Regression Model

Independent Variables	Poisson Regression	Negative Binomial
	Model	Regression Model
	Coefficient	
Age ( <i>Standard Error</i> )	-0.012* (0.0013)	-0.013* (0.0015)
Charlson Comorbidity Index ( <i>Standard Error</i> )	0.114* (0.0082)	0.128* (0.0110)
Race		
Black ( <i>Standard Error</i> )	0.068* (0.0142)	0.084* (0.0171)

Independent Variables	Poisson Regression Model	Negative Binomial Regression Model
	Coefficient	
Asian or Pacific Islander ( <i>Standard Error</i> )	-0.287* (0.0700)	-0.310* (0.0785)
Hispanic or Latina ( <i>Standard Error</i> )	-0.267* (0.0239)	-0.315* (0.0271)
American Indian or Alaskan ( <i>Standard Error</i> )	-0.358** (0.2185)	-0.354** (0.2435)
Obstetric Comorbidity Index ( <i>Standard Error</i> )	0.049* (0.0041)	0.054* (0.0053)
Medicaid Coverage <= 187 days ( <i>Standard Error</i> )	-0.346* (0.0296)	-0.351* (0.0332)
<= 94 days ( <i>Standard Error</i> )	-0.845* (0.0541)	-0.871* (0.0576)
>=280 days ( <i>Standard Error</i> )	0.245* (0.0166)	0.260* (0.0195)
Disability ( <i>Standard Error</i> )	0.196* (0.0267)	0.206* (0.0341)
Inpatient Admission	0.476* (0.0172)	0.520* (0.0223)
Maternal Related ED Visit	2.341* (0.0204)	2.337* (0.0213)
Constant ( <i>Standard Error</i> )	-1.421* (0.0384)	-1.400 (0.0445)
lnalpha (ln( $\alpha$ )) ( <i>Standard Error</i> )		-1.705* (0.0471)
alpha ( $\alpha$ ) ( <i>Standard Error</i> )		0.182* (0.0086)

Independent Variables	Poisson Regression Model	Negative Binomial Regression Model
	Coefficient	
<i>N</i>	23,824	23,824

\* Indicates  $p < .05$ ; and \*\* Indicates  $p > .05$

### 3.4.3 Test Statistic of the Fitted Model for The Negative Binomial Regression Model

The test statistic of the log likelihood of the fitted model for the Negative Binomial regression model showed that all regression coefficients in the model were simultaneously not equal to zero. The Likelihood Ratio Chi-squared test statistic for the model was 18671.15 and was statistically significant at  $p < .001$ . The equation is defined below (negative two times the difference of the log likelihood for the null model and the fitted model).

$$\text{Likelihood Chi-Square} = -2[(-31605.333) - (-22269.759)] = 18671.15.$$

## Chapter 4

### STATISTICAL ANALYSIS RESULTS

This chapter 4 provides the study's empirical findings which were obtained using the Negative Binomial regression model as presented in Chapter 3. The chapter is divided into four sections. Section 4.1 provides a theoretical overview of how to interpret results from the Negative Binomial regression model. Section 4.2 presents the results of the study in terms of factor change (i.e., incident rate ratio) and percent change on the expected count of ED visits for each unit of change for the independent variables. Sections 4.3 and 4.4 present the results of the model in terms of predicted probabilities and marginal effects, respectively.

#### 4.1 Theoretical Overview for Interpreting Results

To interpret the results of the Negative Binomial model, it is important to understand how the model was applied. For this study, the dependent variable of the Negative Binomial regression model was the number of ED visit (count of the number of visits); the log of the expected count is a function of the independent variables for the study (refer to Equation 3.9).

For this study, four approaches were used to interpret the count model:

- factor change (i.e., incidence rate ratio) in the expected count  $\exp(\beta)$  for a unit increase in  $x$ ;
- percent change in the expected count for a unit increase in  $x$ ;
- average predicted probability; and

- marginal effects.

A theoretical overview of each of these is described in Sections 4.1.1-4.1.4.

#### 4.1.1 Factor Change

The regression coefficient ( $\beta$ ) of the Negative Binomial regression model is interpreted as a 1 unit change in the independent variable. The regression coefficient ( $\beta$ ) is the difference of the logs of expected counts ( $\mu$ ), given other independent variables in the model are held constant. It is defined in Equation 4.1.

$$\beta = \log(\mu_{x+1}) - \log(\mu_x) \dots\dots\dots (4.1)$$

where  $\beta$  is the regression coefficient,  $\mu$  is the expected count and  $x$  is the independent variable;  $x$  is evaluated at  $x$  and  $x+1$  which implies a 1 unit change in the independent variable.

In logarithm, the difference of two logs is equal to the log of their quotient:

$$\log(\mu_{x+1}) - \log(\mu_x) = \log\{(\mu_{x+1})/(\mu_x)\}.$$

Thus,

$$\beta = \log\left(\frac{\mu_{x+1}}{\mu_x}\right) \dots\dots\dots (4.2)$$

$$e^\beta = \frac{\mu_{x+1}}{\mu_x} \dots\dots\dots (4.3)$$

The quantity on the right-hand side of Equation 4.2 can be referred to as a count change by factor of  $\exp(\beta)$  for a unit change in  $x$  or as a log of the rate ratio. The latter is referred to as the log of the rate ratio because the number of ED visits during the prenatal period is, by definition, a rate. The rate at which the event occurs is called the incident rate; thus, the coefficients are interpreted in terms of incident rate ratio (IRR) (<https://stats.oarc.ucla.edu/stata/output/poisson-regression>). To

calculate the factor change (IRR), the raw coefficient is exponentiated ( $\exp(\beta)$ ). In this study, factor change and IRR are used interchangeably.

#### 4.1.2 Percent Change

Alternatively, results from the model can be presented as percent change in the expected count for a unit change in  $x_k$ , computed as follows:

$$100 [\exp(\beta_k \times 1) - 1].$$

Results with respect to factor and percent change are presented in Section 4.2.

#### 4.1.3 Predicted Probability

Based on the distribution of counts, the estimated parameters of the Negative Binomial regression model can also be used to compute predicted probabilities of ED visit counts where  $y = k$  (that is, where probability of  $k = 1$ ; probability of  $k = 2$ , etc.) by using the following equations for a given  $x$ :

$$\widehat{Pr}(y = k|x) = \frac{e^{-x\hat{\beta}} (x\hat{\beta})^k}{k!} \dots \dots \dots (4.4)$$

$$\widehat{Pr}(y = k|x) = \frac{\exp(-\hat{\mu}) \hat{\mu}^k}{k!} \dots \dots \dots (4.5)$$

where  $\hat{\mu} = \exp(x\hat{\beta})$ . (Long, 2014). The mean predicted probabilities for ED visits are computed for each count, holding all other predictors at their mean value.

Results of predicted probabilities are presented in Section 4.3.

#### 4.1.4 Marginal Effects

The marginal effects on  $E(y | x)$  (or sometimes referred to as marginal change) allows one to estimate how the count of ED visits (the count outcome) changes when a specific independent variable in the model changes, holding all other

variables in the model constant. As explained by Long and Freese (2014), marginal effects can be computed by taking partial derivative of  $E(y | x)$  with respect to  $x_k$  which can be computed as follows:

$$\frac{\partial E(y | x)}{\partial x_k} = \frac{\partial \exp(x\beta)}{\partial x\beta} \frac{\partial x\beta}{\partial x_k} = \exp(x\beta) \beta_k = E(y|x)\beta_k \dots \dots \dots (4.6)$$

Poisson regression and Negative Binomial regression are nonlinear and therefore, the slope is not constant. Long (2014) notes that value of the marginal effects, or the marginal change from a nonlinear model depends on the coefficient for  $x_k$  as well as the expected value of  $y$  given  $x$ . For  $\beta_k > 0$ , the larger the current value of  $E(y | x)$ , the larger the rate of change; for  $\beta_k < 0$ , the smaller the current value of  $E(y | x)$ , the smaller the rate of change. Because  $E(y | x)$  depends on levels of all variables in the model, the size of marginal change also depends on the level of all variables (Long & Freese, 2014). Marginal effects, or marginal change, can be computed in several ways including marginal effects at the mean (MEM), average marginal effect (AME), and marginal effects at representative values (MER).

The results of marginal effects as presented in Section 4.3 were calculated by taking partial derivative of  $E(y | x)$  with respect to  $x_k$ , and setting all the other independent variables in the model at their observed values.

## 4.2 Factor and Percent Change

Factor and percent change results are provided in Sections 4.2.1 to 4.2.8 based on the eight independent variables: (i) age, (ii) race/ethnicity, (iii) presence of a disability (iv) Charlson Comorbidity Index, (v) Obstetric Comorbidity Index, (vi) duration of Medicaid coverage during the prenatal period prior to delivery, (vii) whether the ED visit resulted in hospitalization, that is, whether it was urgent or not,

and (viii) whether the ED visit was a maternal related visit. Results for each variable are provided below and captured in Table 4.1 found at the end of this section.

#### **4.2.1 Age**

Results from the model revealed that age had a direct impact on the number of ED visits at  $p < .05$ . The raw coefficient ( $\beta$ ) for age was negative, demonstrating that age had a negative impact on the number of ED visits, that is, for an increase in 1 year of age, the expected log count of the number of ED visits will change by  $-0.013$ , holding all other variables in the model constant (see Table 4.1).

In terms of factor change, where the raw coefficient ( $\beta$ ) is exponentiated ( $\exp -0.013$ ), the findings indicated that for every additional year increase in age, the number of ED visits is expected to decrease by a factor of 0.987 (CI, 0.984 - 0.990;  $p < .05$ ), holding all other variables constant.

In terms of percent change in the expected count, the results from the model showed that for every additional year increase in age, the number of ED visits will decrease by 1.3%, holding all other variables constant. The findings on the impact of age on ED visits revealed that younger pregnant women are expected to visit the ED during the prenatal period more than older pregnant women.

#### **4.2.2 Race/Ethnicity**

Race/ethnicity was entered into the model as four dummy variables: Black, Hispanic or Latina, Asian/Pacific Islander, and American Indian or Alaskan. Caucasian race was used in the model as the reference for comparison with each of the four dummy variables.

The estimated coefficient for the dummy variable representing Black was 0.084 and statistically significant at  $p < .05$ . The positive and larger coefficient for the Black variable suggested that the expected log count of number of ED visits for Black was the highest. The estimated coefficient for the dummy variable representing Hispanic or Latina and Asian/Pacific Islander was -0.315 and -0.310, respectively. Both dummy variables were statistically significant at  $p < .05$ . The dummy variable for American Indian or Alaskan was -0.354, with a p-value reported at 0.146, indicating the same impact on number of ED visits as the reference group (see Table 4.1).

The raw coefficient ( $\beta$ ) for Black was 0.084; the fact that it was a positive indicated that pregnant Black women tend to have more ED visits than Caucasian (reference group). The raw coefficient ( $\beta$ ) representing Black women showed that the expected log count of the number of ED visits for Black women was 0.084 greater than the expected log count of the number of ED visits for Caucasian (reference group), holding all other variables in the model constant.

In terms of the factor change, the results from the model indicate that being Black, increased the expected number of ED visits by a factor of 1.088 (CI, 1.052 - 1.125;  $p < .05$ ) compared with Caucasian women, while holding the other variables in the model constant.

In terms of percent change, the results from the model revealed that, compared with Caucasian (reference group), being Black increased the expected number of ED visits by 8.8%, holding all other variables in the model constant.

The raw coefficient of the Hispanic or Latina was negative, indicating that Hispanic or Latina women tended to have less ED visits compared with Caucasian

(reference group). The raw coefficient ( $\beta$ ) was estimated at -0.315 and was statistically significant at  $p < 0.05$ , indicating that the expected log count of the number of ED visits for Hispanic or Latina women was 0.315 less than the expected count log of the number of ED visits for Caucasian women (reference group), holding all other variables constant.

In terms of the factor change, the results from the model indicated that being Hispanic or Latina, decreased the expected number of ED visits by a factor of 0.729 (CI, 0.692 – 0.769;  $p < .05$ ) compared with Caucasian women (reference group), while holding the other variables in the model constant.

In terms of percent change, the results from the model revealed that, compared with Caucasians, being Hispanic or Latina decreased the expected number of ED visits by 27.1%, holding all other variables in the model constant.

The raw coefficient for Asian Pacific Islander was negative, indicating that Asian Pacific Islander women tended to have less ED visits compared with Caucasian (reference group). The raw coefficient ( $\beta$ ) was estimated at -0.310 and was statistically significant at  $p < 0.05$ , indicating that the expected log count of the number of ED visits for Asian Pacific Islander women was 0.310 less than the expected count log of the number of ED visits for Caucasian women (reference group), holding all other variables constant.

In terms of the factor change, the results from the model indicated that being Asian Pacific Islander, decreased the expected number of ED visits by a factor of 0.733 (CI, 0.629 – 0.855;  $p < .05$ ) compared with Caucasian women (reference group), while holding the other variables in the model constant.

In terms of percent change, the results from the model revealed that, compared with Caucasians, being Asian Pacific Islander decreased the expected number of ED visits by 26.7%, holding all other variables in the model constant.

The dummy variable for American Indian/Alaskan was not statistically significant indicating that the variable had the same impact as the variable for Caucasian women (reference group).

Comparing the coefficients, IRR (that is, factor change), and percent change of the three dummy variables representing Black, the Asian/Pacific Islanders, and Hispanic or Latina with Caucasian (reference group), results revealed that Black women had the highest expected number of ED visits, followed by Caucasian women and then Asian/Pacific Islanders. For example, in terms of percent change, (a) being Black increased the expected number of ED visits by 8.8%, while (b) being Asian/pacific Islanders decreased the expected number of ED visits by 26.7%, (c) being Hispanic or Latina decreased the expected number of ED visits by 27.1% compared with Caucasian. In conclusion, among the three race/ethnic groups, being Black had the highest expected number of ED visits.

#### **4.2.3 Presence of Disability**

Pregnant women with a disability were entered into the model as a dummy variable. The findings revealed that the disability variable was statistically significant at  $p < .05$ . The raw coefficient ( $\beta$ ) was positive, indicating the expected log count on the number of ED visits for women with disabilities was 0.206 higher than that for woman without disabilities, holding all other variables in the model constant (see Table 4.1).

In terms of factor change, the results from the model showed that the expected number of ED visits increased by a factor of 1.229 (CI, 1.150 – 1.314;  $p < .05$ ) for women with disabilities compared to those without disabilities, holding all other variables in the model constant.

In terms of percent change the results indicated that the expected number of ED visits increased by 22.9% for disabled women, holding all other variables in the model constant.

#### **4.2.4 Charlson Comorbidity Index**

The Charlson Comorbidity Index, one of two health indices used in the model, was statistically significant at  $p < .05$ . The raw coefficient ( $\beta$ ) was positive, suggesting a positive relationship between Charlson Comorbidity Index scores and the number of ED visits.

The raw coefficient ( $\beta$ ) for Charlson Comorbidity Index was positive, demonstrating that the index score had a positive impact on the number of ED visits, that is, for a 1-unit increase in the score, the expected log count of the number of ED visits will change by 0.128, holding all other variables in the model constant (see Table 4.1).

In terms of factor change, for every 1-unit increase in the score, the number of ED visits was expected to increase by a factor of 1.137 (CI, 1.113 – 1.162;  $p < .05$ ), holding all other variables in the model constant.

In terms of percent change, the results from the model demonstrated that for a 1 unit increase in the Charlson Comorbidity Index score, the number of ED visits should be expected to increase by 13.7%, holding all other variables in the model constant.

#### **4.2.5 Obstetric Comorbidity Index**

The Obstetric Comorbidity Index was statistically significant at  $p < .05$ . The raw coefficient ( $\beta$ ) was positive, suggesting a positive relationship between Obstetric Comorbidity Index scores and the number of ED visits. That is, for a 1-unit increase in the score, the expected log count of the number of ED visits will change by 0.054, holding all other variables in the model constant (see Table 4.1).

In terms of factor change, for every 1-unit increase in the score, the number of ED visits should be expected to increase by a factor of 1.056 (CI, 1.045 – 1.067;  $p < .05$ ), holding all other variables in the model constant.

In terms of percent change, the results from the model demonstrated that for a 1-unit increase in the Obstetric Comorbidity Index score, the number of ED visits was expected to increase by 5.6%, holding all other variables in the model constant.

#### **4.2.6 Duration of Medicaid Coverage**

Three dummy variables were operationalized to represent the duration of Medicaid coverage during the 280 days prior to the delivery: for 280 days (that, is the full prenatal period), from 187 days down to 95 days, and 94 days down to 1 day. All were compared to the reference group of women with Medicaid coverage spanning 279 days to 188 days. All three dummy variables were statistically significant at  $p < .05$  revealing that the length of Medicaid coverage impacted the number of ED visits (see Table 4.1).

The raw coefficient ( $\beta$ ) for the variable representing women with 187 days down to 95 days of Medicaid coverage was -0.351, which indicated that the expected log count of the number of ED visits for those women was 0.351 less than the expected log count of the number of ED visits for women whose coverage was 279

days down to 188 days (reference group), holding all other variables in the model constant.

In terms of factor change and percent change, the results from the model showed the number of ED visits by women with 187 days down to 95 days of Medicaid coverage, was lower than the reference by a factor of 0.704 (CI, 0.660 – 0.752;  $p < .05$ ), that is, the expected number of ED visits by women with 187 days down to 95 days of coverage was 29.6% lower than women in the reference, holding all other variables in the model constant.

As expected, women with up to 94 days' coverage were expected to have fewer ED visits than women in the reference group. The raw coefficient ( $\beta$ ) was -0.871 suggesting that the expected log count of number of ED visits for women with up to 94 days coverage was 0.871 lower than those in the reference group.

In terms of factor change and percent change, the results from the model showed that the number of ED visits by women with up to 94 days of Medicaid coverage was lower than those in the reference group by a factor of 0.419 (CI, 0.374-0.469;  $p < .05$ ); that is, the expected number of ED visits by women with up to 94 days of coverage was 58.1% lower than the expected number of ED visits for women in the reference group, holding all other variables in the model constant.

The results from the model for the dummy variable representing women with Medicaid coverage throughout the prenatal period (at least 280 days) confirmed that women in this group used the ED more than those in the reference group. The raw coefficient ( $\beta$ ) for the variable representing those women who had at least 280 days of Medicaid coverage was estimated to be 0.260, indicating that the expected log count of number of ED visits for women with at least 280 days of Medicaid coverage was

0.260 larger than the expected log count of number of ED visits of those women in the reference group, holding all other variables in the model constant.

In terms of factor change and percent change, the expected number of ED visits by women with full Medicaid coverage throughout the prenatal period was greater than women in the reference group by a factor of 1.297(CI, 1.248 – 1.348;  $p < .05$ ); that is, the expected number of ED visits by women with full Medicaid coverage was 29.7% higher than women in the reference group, holding the other variables in the model constant.

Comparison of the raw coefficients, factor change, and percent change for each of the three dummy variables representing Medicaid coverage (at least 280 days, between 187 days and 95 days, and between 94 days and 1 day) with the reference coverage (between 279 days and 88 days) revealed that women with full Medicaid coverage had the highest expected number of ED visits. Women with Medicaid coverage of between 279 days and 188 days had the second highest expected number of ED visits, followed by women with Medicaid coverage of 187 and 95 days. Women with Medicaid coverage of between 94 days and 1 day had the lowest expected number of ED visits.

#### **4.2.7 Inpatient Admission 24 Hours after ED Visit**

To measure the urgency of ED visits, a dummy variable was included in the model indicating whether the ED visit resulted in an inpatient admission within 24 hours. Findings revealed that inpatient admission within 24 hours of an ED visit variable was statistically significant at  $p < .05$  (see Table 4.1).

The variable's raw coefficient ( $\beta$ ) was estimated at 0.520, indicating that the expected log count of the number of ED visits for pregnant women who had an

inpatient visit within 24 hours of their ED visit was 0.520 greater than the expected log count of number of ED visits for women in the reference group including those who did not visit the ED and those who visited the ED but were not admitted to inpatient service (see Table 4.1).

In terms of factor and percent change, the expected number of ED visits by women who visited the ED and were admitted to inpatient care within 24 hours was higher than for women in the reference group by a factor of 1.681(CI, 1.609 – 1.757;  $p < .05$ ). To measure as the percent change, the expected number of ED visits by women who visited the ED and were admitted to inpatient care within 24 hours was 68.1% greater than for women in the reference group, while holding other variables in the model constant.

#### **4.2.8 Maternal Related ED Visits**

A dummy variable was entered into the model to indicate whether the ED visit was for a maternal related condition or not. Findings revealed that the maternal related ED visit variable was statistically significant at  $p < .05$  (see Table 4.1).

The variable's raw coefficient ( $\beta$ ) was estimated at 2.337, indicating that the expected log count of the number of ED visits for pregnant women who had a maternal related condition at the time of the ED visit was 2.337 greater than the expected log count of the number of ED visit for women in the reference group including those who did not visit the ED and those who visited the ED but did not have a maternal related condition at the time of the ED visit (see Table 4.1).

In terms of factor change and percent change, the expected number of ED visits by women who visited the ED for maternal related conditions was greater than women in the reference group by a factor of 10.354 (CI, 9.930 – 10.796;  $p < .05$ ),

holding all other variable in the model constant. In terms of percent change, the expected number of ED visits for women who visited the ED for maternal related conditions was 935.4% greater than for women in the reference group.

Table 4.1: Estimated Raw Coefficient, Factor Change or Incident Rate Ratio (IRR), and Percent Change from Negative Binomial Regression Model

Independent Variable	Raw Coefficient ( $\beta$ )	95% Confidence Interval		Factor Change/IRR $\exp(\beta)$	Percent Change (%)
Age <i>z-score</i>	-0.013* (-8.85)	-0.016	-0.010	0.987* (-8.85)	-1.3%
Race					
Black <i>z-score</i>	0.084* (4.89)	0.050	0.118	1.088* (4.89)	8.8%
Asian or Pacific Islander <i>z-score</i>	-0.310* (-3.95)	-0.464	-0.156	0.733* (-3.95)	-26.7%
Hispanic or Latina <i>z-score</i>	-0.315* (-11.62)	-0.369	-0.262	0.729* (-11.62)	-27.1%
American Indian or Alaskan <i>z-score</i>	-0.354** (-1.45)	-0.831	0.123	0.702** (-1.45)	-29.8%
Charlson Comorbidity Index <i>z-score</i>	0.128* (11.67)	0.107	0.150	1.137* (11.67)	13.7%
Obstetric Comorbidity Index <i>z-score</i>	0.054* (10.29)	0.044	0.064	1.056* (10.29)	5.6%
Medicaid Coverage <=187-95 Days <i>z-score</i>	-0.351* (-10.57)	-0.416	-0.286	0.704* (10.57)	-29.6%

Independent Variable	Raw Coefficient ( $\beta$ )	95% Confidence Interval		Factor Change/IRR $\exp(\beta)$	Percent (%) Change
$\leq 94$ -1 Days <i>z-score</i>	-0.871* (-15.11)	-0.984	-0.758	0.419* (15.11)	-58.1%
$\geq 280$ Days <i>z-score</i>	0.260* (13.34)	0.222	0.298	1.297* (13.34)	29.7%
Disability <i>z-score</i>	0.206* (6.05)	0.139	0.273	1.229* (6.05)	22.9%
Inpatient Admission <i>z-score</i>	0.520* (23.25)	0.476	0.563	1.681* (23.25)	68.1%
Maternal Related ED Visit <i>z-score</i>	2.337* (109.65)	2.295	2.379	10.354* (109.65)	935.4%
Constant <i>z-score</i>	-1.400* (-31.45)	-1.487	-1.313	0.247* (-31.45)	
Inalpha <i>Standard Error</i>	-1.705* (0.047)	-1.798	-1.613	-1.705* (0.047)	
alpha <i>Standard Error</i>	0.182* (0.008)	0.166	0.199	0.182* (0.008)	
N	23,824			23,824	

\*Indicates  $p < .05$ ; and \*\* Indicate  $p > .05$

Percent (%) indicates percent change in expected count for one-unit increase in  $x$

### 4.3 Average Predicted Probabilities on the Number of ED Visits

Average predicted probabilities on the number of ED visits offered another way to present the Negative Binomial regression model results. Section 4.3.1 provides a comparison of observed average probabilities on the number of ED visits with the average predicted probabilities from the Negative Binomial regression

model. Sections 4.3.2 – 4.3.9 provide specific information to predict the probability of a pregnant woman with a specific profile making one, or two, or three, or four, or five...twenty-five ED visits. The results were based on the eight independent variables: (i) age, (ii) race/ethnicity, (iii) presence of a disability (iv) Charlson Comorbidity Index, (v) Obstetric Comorbidity Index, (vi) duration of Medicaid coverage during the prenatal period prior to delivery, (vii) whether the ED visit resulted in hospitalization, that is whether it was urgent or not, and (viii) whether the ED visit was a maternal related visit. The average predicted probabilities of ED visits are presented for each independent variables holding all others constant at the mean value. The results of the average predicted probabilities of ED visits for each independent variable complements and reinforces the findings of factor and percent change, as presented in Section 4.2.

The results for each variable are captured in Tables 4.3-4.10.

#### **4.3.1 Comparison of Observed and Predicted Probabilities**

Comparison of observed average probabilities on the number of ED visits with the average predicted probabilities from the Negative Binomial regression model reveals that the model performed very well. As shown in Figure 4.1 and Table 4.2, the model slightly over predicts zero visits (0.62 versus 0.59) and under predict one and two visits by 0.01. Beyond two visits the average predicted probabilities estimated from the model are very close or on par with the observed probabilities. The results are presented in Figure 4.1 and Table 4.2 from zero to 10 ED visits (note: number of ED visits for the study population ranged from zero to 25).

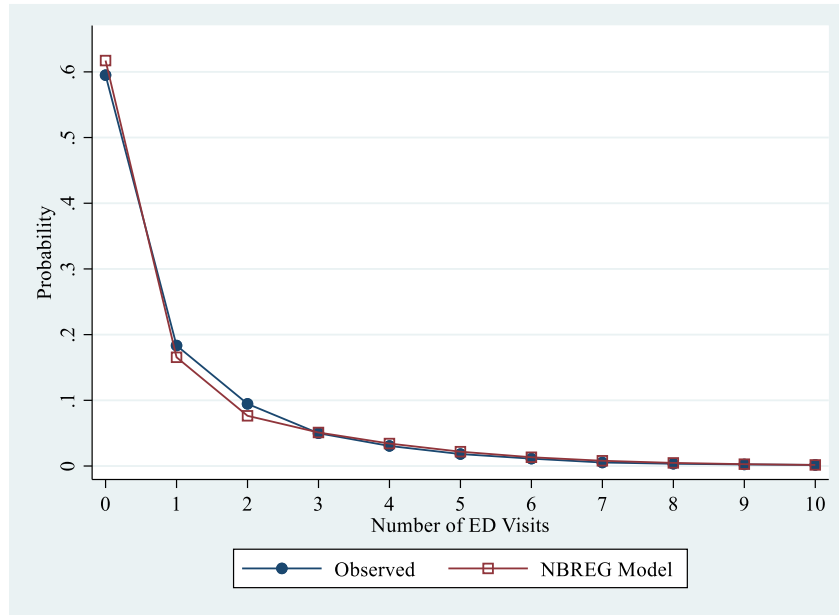


Figure 4.1: Average Predicted Probabilities on Number of ED Visits from the Negative Binomial Regression Model and Observed Proportion

Table 4.2: Comparison of Average Predicted Probabilities on the Number of Emergency (ED) Visits from the Model and Observed Proportion

	Number of ED Visits										
	0	1	2	3	4	5	6	7	8	9	10
Observed	0.59	0.18	0.09	0.05	0.03	0.02	0.01	0.005	0.003	0.002	0.002
Predicted	0.62	0.17	0.08	0.05	0.03	0.02	0.01	0.008	0.005	0.003	0.002

### 4.3.2 Age

Table 4.3 captures the average predicted probabilities of ED visits by age, holding all independent variables constant. The results are presented for up to five ED visits. Given that the dependent variable is a count and has a Poisson distribution, Table 4.3 clearly shows the average predicted probabilities for ED visits increased

with age for those who never visited the ED (zero visits). Conversely, for those using the ED, the average predicted probability decreased with age.

A closer review of the findings revealed that the average predicted probability among women who made only one ED visit decreased slightly as age increased. As shown in Table 4.3, for those who visited the ED once, the average predicted probability dropped from 0.277 for the lowest age to 0.211 among the oldest women in the study population (45 years old). The model also showed that within each age group the average predicted probabilities decline as number of ED visits increased.

Table 4.3: Predicted Probabilities of ED Visits by Age

Age	Average Predicted Probabilities					
	Zero Visit	One Visit	Two Visits	Three Visits	Four Visits	Five Visits
10	0.634	0.277	0.072	0.014	0.002	0.000
11	0.638	0.275	0.070	0.014	0.002	0.000
12	0.641	0.274	0.069	0.013	0.002	0.000
13	0.645	0.272	0.068	0.013	0.002	0.000
14	0.649	0.270	0.066	0.013	0.002	0.000
15	0.652	0.268	0.065	0.012	0.002	0.000
16	0.656	0.266	0.064	0.012	0.002	0.000
17	0.659	0.264	0.063	0.011	0.002	0.000
18	0.663	0.263	0.061	0.011	0.002	0.000
19	0.666	0.261	0.060	0.011	0.002	0.000
20	0.670	0.259	0.059	0.010	0.002	0.000
21	0.673	0.257	0.058	0.010	0.001	0.000
22	0.677	0.255	0.057	0.010	0.001	0.000
23	0.680	0.253	0.056	0.009	0.001	0.000
24	0.684	0.251	0.055	0.009	0.001	0.000
25	0.687	0.249	0.054	0.009	0.001	0.000
26	0.690	0.247	0.052	0.009	0.001	0.000
27	0.693	0.246	0.051	0.008	0.001	0.000
28	0.697	0.244	0.050	0.008	0.001	0.000
29	0.700	0.242	0.049	0.008	0.001	0.000

30	0.703	0.240	0.048	0.007	0.001	0.000
31	0.706	0.238	0.047	0.007	0.001	0.000
32	0.710	0.236	0.046	0.007	0.001	0.000
33	0.713	0.234	0.045	0.007	0.001	0.000
34	0.716	0.232	0.045	0.007	0.001	0.000
35	0.719	0.230	0.044	0.006	0.001	0.000
36	0.722	0.228	0.043	0.006	0.001	0.000
37	0.725	0.226	0.042	0.006	0.001	0.000
38	0.728	0.225	0.041	0.006	0.001	0.000
39	0.731	0.223	0.040	0.006	0.001	0.000
40	0.734	0.221	0.039	0.005	0.001	0.000
41	0.737	0.219	0.038	0.005	0.001	0.000
42	0.740	0.217	0.038	0.005	0.001	0.000
43	0.743	0.215	0.037	0.005	0.001	0.000
44	0.746	0.213	0.036	0.005	0.001	0.000
45	0.748	0.211	0.035	0.005	0.000	0.000

Specified values of covariates in the model:

Charlson Comorbidity Index	Black	Caucasian	Hispanic or Latina	American Indian or Alaskan	Maternal Comorbidity Index
0.209	0.366	0.374	0.239	0.00168	0.821
<=187 days	<=94 days	> 280 days	Disability	Inpatient 24 hrs After ED	Maternal Related ED Visit
0.164	0.0949	0.492	0.0345	0.0557	0.319

### 4.3.3 Race/Ethnicity

The average predicted probabilities for race/ethnicity in the model complemented the findings in Section 4.2.2. Using average predicated probabilities, pregnant Black and Caucasian women had lower average predicted probabilities for not visiting the ED compared to other races. The average predicted probability for zero visits among Black and Caucasian women was lowest among the five races, estimated at 0.652 and 0.674, respectively (see Table 4.4).

Black and Caucasian women who visited the ED had higher average predicted probabilities compared to other races. The average predicted probabilities for Caucasian women visiting one to five times ranged from 0.257 to close to zero probability (0.001) for four visits and zero probability for five visits. The average predicted probabilities for Blacks women showed similar results to those for Caucasian women, but the average predicted probabilities were slightly higher, ranging from 0.268 for the one visit to 0.002 for four visits and zero for five visits.

On the other hand, the average predicted probability among Hispanic or Latina pregnant women who never visited the ED, was estimated at 0.748 which is the same as that for Asian/Pacific Islanders (0.747), but slightly lower than that for American Indian/Alaskan women (0.756). The findings provided additional evidence that ED visits by pregnant women vary from one race/ethnicity to another.

Table 4.4: Predicted Probabilities of ED Visits by Race/Ethnicity

Race	Average Predicted Probabilities					
	Zero visit	One Visit	Two Visits	Three Visits	Four Visits	Five Visits
Asian	0.747	0.212	0.036	0.005	0.001	0.000
Black	0.652	0.268	0.065	0.012	0.002	0.000
Caucasian	0.674	0.257	0.058	0.010	0.001	0.000
Hispanic or Latina	0.748	0.212	0.035	0.005	0.000	0.000
American Indian or Alaskan	0.756	0.206	0.033	0.004	0.000	0.000
Specified values of covariates) in the model:						
Age	Charlson Comorbidity Index	Maternal Comorbidity Index	<=187 days	<=94 days	>=280 days	
25	0.209	0.821	0.164	0.0949	0.492	

Disability	Inpatient 24 hrs After ED	Maternal Related ED Visit
0.0345	0.056	0.319

Note: In this table the predicted probabilities are shown up to five visits only.

#### 4.3.4 Presence of Disability/ies

Pregnant women with disabilities had a lower average predicative probability for never attending the ED; as the numbers of ED visit increased, women with disabilities had a higher average predicted probability for attending the ED than women without disabilities. However, the model showed that the average predicted probability of ED visits (either one, or two, or three, or four visits) among women with disabilities were only slightly higher than for those without disabilities (for example, one visit was 0.248 versus 0.277, for two visits 0.053 versus 0.071, etc.) (see Table 4.5).

Table 4.5: Predicted Probabilities of ED Visits by Disability

Disability	Average Predicted Probabilities					
	Zero Visit	One Visit	Two Visits	Three Visits	Four Visits	Five Visits
No	0.689	0.248	0.053	0.009	0.001	0.000
Yes	0.635	0.277	0.071	0.014	0.002	0.000
Specified values of covariates in the model:						
Age	Charlson Comorbidity Index	Black	Caucasian	Hispanic or Latina	American Indian or Alaskan	Maternal Comorbidity Index
25	0.209	0.366	0.374	0.239	0.00168	0.821
<=187 days	<=94 days	>=280 days	Inpatient 24 hrs After ED	Maternal Related ED Visit		
0.164	0.0949	0.492	0.056	0.319		

Note: In this table the predicted probabilities are shown up to five visits only.

### 4.3.5 Charlson Comorbidity Index

Corresponding to the findings from factor and percent change, the average predicted probability on the number of ED visits demonstrated that as the Charlson Comorbidity Index scores increased, the average predicted probabilities for never attending the ED decreased (see Table 4.6). For pregnant women who made one, two, three, four, or five ED visits, the average predicted probabilities increased as the Charlson Comorbidity Index score increased, suggesting that the index was a good predictor for those who visited the ED. The results from the model confirmed that women with poorer general health conditions have a higher chance of visiting ED.

The model consistently showed that among pregnant women with the same Charlson Comorbidity Index score, the average predicted probability of making an ED visit declined as the number of ED visits increased. As illustrated in the following example, among women with a Charlson Comorbidity Index score of 4 or 5, the average predicted probability of making one ED visit was 0.312 and 0.323, respectively. For women with the same scores, the average predicted probabilities of making five visits were 0.001 and 0.002, respectively.

Table 4.6: Predicted Probabilities of ED Visits by Charlson Comorbidity Index

Charlson Comorbidity Index	Average Predicted Probabilities					
	Zero Visit	One Visit	Two Visits	Three Visits	Four Visits	Five Visits
0	0.694	0.246	0.051	0.008	0.001	0.000
1	0.661	0.264	0.062	0.011	0.002	0.000
2	0.626	0.281	0.075	0.015	0.003	0.000
3	0.589	0.297	0.089	0.020	0.004	0.001
4	0.550	0.312	0.104	0.027	0.006	0.001
5	0.509	0.323	0.121	0.035	0.009	0.002
6	0.467	0.332	0.140	0.045	0.012	0.003
7	0.424	0.337	0.158	0.057	0.018	0.005

8	0.381	0.337	0.176	0.071	0.024	0.007
9	0.338	0.333	0.194	0.087	0.033	0.011
10	0.296	0.323	0.209	0.104	0.044	0.017
<b>Specified values of covariates in the model:</b>						
<b>Age</b>	<b>Black</b>	<b>Caucasian</b>	<b>Hispanic or Latina</b>	<b>American Indian or Alaskan</b>	<b>Charlson Comorbidity Index</b>	<b>&lt;=187 days</b>
25	0.366	0.374	0.239	0.00168	0.821	0.164
<b>&lt;=94 days</b>	<b>&gt;=280 days</b>	<b>Disability</b>	<b>Inpatient 24 hrs After ED</b>	<b>Maternal Related ED Visit</b>		
0.0949	0.492	0.0345	0.056	0.319		

Note: In this table the predicted probabilities are shown up to five visits only.

#### 4.3.6 Obstetric Comorbidity Index

The average predicted probability on the number of ED visits demonstrated that as the Obstetric Comorbidity Index scores increased, the average predicted probabilities for never attending the ED decreased (see Table 4.7). For pregnant women who made one, two, three, four, or five ED visits, the average predicted probabilities increased as the Obstetric Comorbidity Index scores increased. The results from the model confirmed that women with poorer obstetrical health have a higher chance of visiting the ED. The model consistently showed that among women with the same Obstetric Comorbidity Index score, the average predicted probability of making an ED visit decreased as the number of ED visits increased. For example, among women with an Obstetric Comorbidity Index of 6 or 7, the average predicted probability of making one ED visit was 0.288 or 0.294, respectively. For women with the same scores, the average predicted probabilities of making four visits were 0.003 and 0.004, respectively, and the average predicted probability of making five visits was 0.001 for women with scores 6 or 7.

Table 4.7: Predicted Probabilities of ED Visits by Obstetric Comorbidity Index

Obstetric Comorbidity Index	Average Predicted Probabilities					
	Zero Visit	One Visit	Two Visits	Three Visits	Four Visits	Five Visits
0	0.698	0.243	0.050	0.008	0.001	0.000
1	0.685	0.251	0.054	0.009	0.001	0.000
2	0.671	0.258	0.059	0.010	0.002	0.000
3	0.657	0.266	0.064	0.012	0.002	0.000
4	0.642	0.273	0.069	0.013	0.002	0.000
5	0.627	0.281	0.074	0.015	0.003	0.000
6	0.612	0.288	0.080	0.017	0.003	0.001
7	0.596	0.294	0.086	0.019	0.004	0.001
8	0.580	0.301	0.092	0.022	0.004	0.001
9	0.563	0.307	0.099	0.024	0.005	0.001
10	0.547	0.313	0.106	0.027	0.006	0.001
11	0.530	0.318	0.113	0.031	0.007	0.001
12	0.512	0.323	0.120	0.034	0.008	0.002
13	0.495	0.327	0.128	0.038	0.010	0.002

Specified values of covariates in the model:

	Obstetric Comorbidity Index	Black	Caucasian	Hispanic or Latina	American Indian or Alaskan	<=18 days
Age						
25	0.209	0.366	0.374	0.239	0.00168	0.164
			Inpatient 24 hrs After ED	Maternal Related ED Visit		
<=94 days	>=280 days	Disability				
0.0949	0.492	0.0345	0.056	0.319		

Note: In this table the predicted probabilities are shown up to five visits only.

### 4.3.7 Duration of Medicaid Coverage

The model showed that pregnant women who had full Medicaid coverage (at least =280 days) throughout their pregnancy had the lowest average predicted probability (0.614) of never attending the ED, compared with the average predicted probabilities for the groups who had partial coverage during the prenatal period.

As shown in Table 4.8, the average predicted probabilities of no ED visit increased from 0.684 among women with fewer than 280 days of Medicaid coverage to 0.763 and 0.850 among women with fewer than 188 days and fewer than 95 days of Medicaid coverage, respectively. For one or more visits to the ED, the average predicted probabilities for women with full Medicaid coverage were highest, compared with the three other groups who had partial Medicaid coverage, ranging from 0.287 for one visit to 0.003 for four visits and zero probability for five visits. For women with the shortest duration of Medicaid coverage, the average predicted probability for one visit and more visits was lowest, ranging from only 0.136 for one visit, to close to zero probability for three visits, and zero probability for four or five visits, respectively. The relationship between length of Medicaid coverage and average predicted probabilities of ED visit was as expected, since a shorter coverage provided a shorter window of opportunity for the women to utilize the ED.

Table 4.8: Predicted Probabilities of ED Visits by Duration of Medicaid Coverage

Medicaid Coverage	Average Predicted Probabilities					
	Zero Visit	One Visit	Two Visits	Three Visits	Four Visits	Five Visits
>=280 days	0.614	0.287	0.079	0.017	0.003	0.000
<=279-188 days	0.684	0.251	0.054	0.009	0.001	0.000
<=187-95 days	0.763	0.201	0.031	0.004	0.000	0.000
<=94-1 days	0.850	0.136	0.013	0.001	0.000	0.000
Specified values of covariates in the model:						
Age	Charlson Comorbidity Index	Black	Caucasian	Hispanic or Latina	American Indian or Alaskan	Maternal Comorbidity Index
25	0.209	0.366	0.374	0.239	0.00168	0.821

	Inpatient 24 hrs After ED	Maternal Related ED Visit
Disability	0.0345	0.319

Note: In this table the predicted probabilities are shown up to five visits only.

#### 4.3.8 Inpatient Admission 24 Hours After ED Visit

Pregnant women who were admitted to the inpatient service within 24 hours of their ED visit had a lower average predicted probability (0.548) for never attending the ED than for women in the reference group (0.694) which included women who never visited the ED and women who visited but were not admitted for inpatient care. The model showed that the average predicted probabilities of ED visits (either one, or two, or three, or four visits) among women admitted to inpatient care were higher than those in the reference group (e.g., for one visit 0.312 versus 0.245, for two visits 0.105 versus 0.051, etc.). In addition, the model showed that the average predicted probability for making an ED visit declined as the number of ED visits increased for women in both groups (see Table 4.9).

Table 4.9: Predicted Probabilities of ED Visits by Inpatient Admission 24 Hours After ED Utilization

Inpatient Admission	Average Predicted Probabilities					
	Zero Visit	One Visit	Two Visits	Three Visits	Four Visits	Five Visits
No	0.694	0.245	0.051	0.008	0.001	0.000
Yes	0.548	0.312	0.105	0.027	0.006	0.001
Specified values of covariates in the model:						
	Charlson Comorbidity Index	Black	Caucasian	Hispanic or Latina	American Indian or Alaskan	Maternal Comorbidity Index
Age	25	0.209	0.366	0.374	0.239	0.00168
						0.821

<=187 days	<=94 days	>=280 days	Disability	Maternal Related ED Visit
0.164	0.0949	0.492	0.0345	0.319

Note: In this table the predicted probabilities are shown up to five visits only.

### 4.3.9 Maternal Related ED Visits

As expected, pregnant women who had a maternal related health condition at the ED visit, had a lower (0.194) average predicted probability for never attending the ED compared to the reference group (0.834), which included women who never visited the ED and women who visited but did not have a maternal related condition at the time of the visit. The model showed that the average predicted probabilities of ED visits (either one, or two, or three, or four visits) among women with a maternal related health condition were higher than those in the reference group (e.g., for one visit 0.275 versus 0.149, for two visits 0.231 versus 0.016, etc.). In addition, the model showed that the average predicted probability for making an ED visit declined as the number of ED visits increased for women in both groups (see Table 4.10).

Table 4.10: Predicted Probabilities of ED Visits by Maternal Related ED Visit

Maternal Related Condition	Average Predicted Probabilities					
	Zero Visit	One Visit	Two Visits	Three Visits	Four Visits	Five Visits
No	0.834	0.149	0.016	0.001	0.000	0.000
Yes	0.194	0.275	0.231	0.149	0.081	0.040
Specified values of covariates) in the model:						
Age	Charlson Comorbidity Index	Black	Caucasian	Hispanic or Latina	American Indian or Alaskan	Maternal Comorbidity Index
25	0.209	0.366	0.374	0.239	0.00168	0.821
<=187 days	<=94 days	>=280 days	Disability	Inpatient 24 hrs After ED		

0.164	0.0949	0.492	0.0345	0.056
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Note: In this table the predicted probabilities are shown up to five visits only.

#### 4.4 Predictive Margins and Average Marginal Effects

The predicted number of ED visits from the overall model was estimated at 0.972, ranging between 0.956 and 0.987, at 95% confidence interval and was statistically significant ( $z = 123.41$ ,  $p < .05$ ). The estimated prediction for the overall model does not by itself provide a useful explanation for the number of ED visits. Therefore, presenting marginal effects allows estimation of how the count of ED visits (the count outcome) changes when a specific independent variable in the model changes, holding all other variables in the model constant.

Sections 4.4.1 - 4.4.7 provides the predictive margins on the number of ED visits, as well as the marginal effect for each independent variable in the model, holding all other variables constant at their observed value.

The results for the predictive margin on number of ED visits for the three continuous variables in the model are presented in Tables 4.11 – 4.13 (age, Charlson Comorbidity Index, and Obstetric Comorbidity Index, respectively). The results for the predictive margin on number of ED visits for the factor variables entered in the model are presented in Table 4.14 (race/ethnicity, disability, Medicaid coverage duration, inpatient admission, and maternal related visit). Refer to Table 4.15 for average margin effects for all variables in the model.

##### 4.4.1 Age

As shown in Table 4.11, holding all other variables at their observed values, and holding age at 10 years (the age of the youngest pregnant female in this analysis), the predictive margin on the number of ED visits was estimated at 1.180 visits and

declined to about 1.03 visits when age was held at 20 years. The predictive margins on the number of ED visits eventually dropped to less than one visit (or only 0.739 visit) when age was held at 45 years (the age of the oldest women in the analysis). Overall, as shown in Table 4.15, the average marginal effects of age was estimated at -0.013 and statistically significant at  $p < .05$ . This means that, with all other variables in the model held constant at their observed values, on average, a 1-year increase in age decreased the expected number of ED visits by 0.013. The average marginal effects were low because the age increase was only 1 year. However, when comparing the predictive margins on the number of ED visits at any two levels of age, for example at 15 and 20 years old, the ratio was  $(1.03268/1.10401) = 0.93539$ . The ratio matched the factor change and the percent change for age in the model, that is, 0.987 for 5 years change:  $0.987^5 = 0.935$ .

Table 4.11: Predictive Margins on Number of ED Visits at Specified Age

Age (Years Old)	Predictive Margins on the Number of ED Visits	Delta-Method		P>z	95% Confidence Interval]	
		Standard Error	z-value			
10	1.180	0.0276	42.72	0	1.126	1.234
15	1.104	0.0183	60.46	0	1.068	1.140
20	1.033	0.0101	94.09	0	1.011	1.054
25	0.966	0.0079	122.88	0	0.951	0.981
30	0.904	0.0104	86.59	0	0.883	0.924
35	0.845	0.0150	56.40	0	0.816	0.875

40	0.791	0.0195	40.51	0	0.752	0.829
45	0.739	0.0236	31.34	0	0.693	0.786

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#### 4.4.2 Race/Ethnicity

As shown table 4.14, the results from the model showed the predictive margins on the number of ED visits for all five race/ethnic groups, holding all other variables at their observed value. The predictive margins on the number of ED visits for Black women was the highest, estimated at about one visit (1.054) followed by Caucasian women (0.969), Asian/Pacific Islanders (0.710), Hispanic or Latina (0.707), and American Indian and Alaskans (0.680), respectively.

Comparison of the predictive margins on the number of ED visits for Caucasian (reference group) with that of other race/ethnic group showed that the results matched the factor change. For example, the ratio between Black and Caucasian women was  $(1.054/.969) = 1.088$ . The ratio matched the factor change and percent change for the dummy variable representing Black when compared with Caucasian. The factor change in the model was 1.088 (for 1 versus baseline 0) =  $1.088^1 = 1.088$ . A similar explanation can be applied to all other races/ethnicities.

The differences in the expected numbers of ED visits between each race/ethnic group and the reference were statistically significant. As shown in Table 4.15, comparing with the reference group (Caucasian), and holding all other variables at their observed value, the average marginal effects of Black women was estimated at 0.085 and statistically significant at ( $z = 4.91, p < .05$ ). The average marginal effects of Asian Pacific Islander women was estimated at -0.259 and was statistically

significant ( $z = -4.58, p < .05$ ). The average marginal effects of Hispanic or Latina women was estimated at  $-0.262$  and was statistically significant ( $z = -12.53, p < .05$ ).

These results showed that, compared with Caucasian, being Black increased the predicted number of ED visits by  $0.085$ ; being Hispanic or Latina or Asian Pacific Islander decreased the predicted number of ED visits by  $-0.262$  and  $-0.259$ , respectively. The dummy variables for American Indian or Alaskan was not statistically significant indicating that the average marginal effects for American Indian or Alaskan were the same as for Caucasian (reference group).

#### **4.4.3 Presence of a Disability**

With all other variables in the model held at the observed values, the predictive margins on the number of ED visits for pregnant women with a disability was estimated at slightly more than one visit,  $1.179$ , whereas the predictive margins on the number of ED visits among women without disability was estimated at  $0.959$  (see Table 4.14). These results matched the factor and percent change findings, as the ratio between disabled and non-disabled women ( $1.179/0.959$ ) was  $= 1.229$ , which indicated that being disabled increases the number of ED visits by  $22.9\%$ . The average marginal effects for being disabled was estimated at  $0.220$  and statistically significant ( $z = 5.53, p < .05$ ), holding all other variables at their observed value (see Table 4.15). This means that compared with women without disabilities we can expect the number of ED visits by pregnant women with disabilities to increase by  $0.220$ . In other words, the difference in the number of ED visits between women with disabilities and those without disabilities was  $0.220$  and statistically significant.

#### **4.4.4 Charlson and Obstetric Comorbidity Index**

Tables 4.12 and 4.13 show the predictive margin on the number of ED visits from the model at each specific score for the Charlson Comorbidity and Obstetric Comorbidity Indices, with all other variables in the model held at their observed values.

The results from the model for the Charlson Comorbidity Index revealed that the predictive margins on the number of ED visits by pregnant women with a 0 score (that is, no health risk) was slightly less than one visit (0.927) (see Table 4.12). As the Charlson Comorbidity Index score increased to 10, the predictive margins on the number of ED visits rose to 3.344 visits.

The predictive margins on the number of ED visits shown in Table 4.12 match the factor and percent change findings as presented earlier in Section 4.2.4. For example, the ratio of the predictive margins on the number of ED visits for scores 0 and 1 ( $1.054/0.927$ ), or 2 and 3 ( $1.363/1.199$ ), or 8 and 9 ( $2.941/2.587$ ) are all equal to the factor change results for this variable (1.137).

The average marginal effects of the Charlson Comorbidity Index, holding all other variables in the model at their observed value, was estimated at 0.125 ( $z = 11.56, p < .05$ ) (see Table 4.15). This means that, on average, one can expect the number of ED visits to increase by 0.125 for every 1-unit increase in the score of Charlson Comorbidity Index.

Table 4.12: Predictive Margins on the Number of ED Visits by Charlson Comorbidity Index Score

Charlson Comorbidity Index	Predictive Margins On the Number of ED Visits	Delta-Method		P>z	95% Confidence Interval]	
		Standard Error	z-value			
0	0.927	0.0083	111.21	0	0.911	0.944
1	1.054	0.0113	93.53	0	1.032	1.076
2	1.199	0.0237	50.67	0	1.152	1.245
3	1.363	0.0410	33.22	0	1.282	1.443
4	1.549	0.0632	24.51	0	1.425	1.673
5	1.761	0.0909	19.37	0	1.583	1.939
6	2.002	0.1251	16.00	0	1.757	2.247
7	2.276	0.1671	13.62	0	1.948	2.603
8	2.587	0.2182	11.86	0	2.160	3.015
9	2.941	0.2803	10.49	0	2.392	3.491
10	3.344	0.3553	9.41	0	2.647	4.040

With respect to the impact of the Obstetric Comorbidity Index on the predictive margins on the number of ED visits, the model showed that the index had a lower impact than the Charlson Comorbidity Index. As shown in Table 4.13, the predictive margins on the number of ED visits among women with a 0 score (that is, no health risk) was slightly less than one visit (0.912). As the Obstetric Comorbidity Index scores increased to the maximum score of 13, the predictive margins on the number of ED visits rose to 1.843, illustrating less impact compared to the Charlson Comorbidity Index. As with the Charlson Comorbidity Index, the results from the predictive margins on the number of ED in Table 4.13 can be used to demonstrate

that the results match the factor and percent change findings as presented earlier in Section 4.2.5.

The average marginal effects of the Obstetric Comorbidity Index, holding all other variables in the model at their observed value, was estimated at 0.053 ( $z = 10.21$ ,  $p < .05$ ) (see Table 4.15). This means that, on average, one can expect the number of ED visits to increase by 0.053 for every 1-unit increase in the Obstetric Comorbidity Index score.

Table 4.13: Predictive Margins on the Number of ED Visits by Obstetric Comorbidity Index Score

Obstetric Comorbidity Index	Predictive Margins on the Number of ED Visits	Delta-Method		P>z	95% Confidence Interval]	
		Standard Error	z-value			
0	0.912	0.0092	98.63	0	0.8938	0.9300
1	0.963	0.0078	123.22	0	0.9473	0.9779
2	1.016	0.0093	108.93	0	0.9979	1.0344
3	1.073	0.0135	79.54	0	1.0462	1.0991
4	1.132	0.0192	59.01	0	1.0947	1.1699
5	1.195	0.0260	46.05	0	1.1444	1.2461
6	1.262	0.0337	37.49	0	1.1957	1.3276
7	1.332	0.0423	31.52	0	1.2490	1.4146
8	1.406	0.0518	27.14	0	1.3044	1.5074
9	1.484	0.0623	23.82	0	1.3619	1.6062
10	1.567	0.0739	21.20	0	1.4217	1.7113

Obstetric Comorbidity Index	Predictive Margins on the Number of ED Visits	Delta-Method		P>z	95% Confidence Interval]	
		Standard Error	z-value			
11	1.654	0.0866	19.10	0	1.4840	1.8233
12	1.746	0.1005	17.37	0	1.5487	1.9425
13	1.843	0.1157	15.93	0	1.6159	2.0693

#### 4.4.5 Duration of Medicaid Coverage

The results from the model demonstrated that the longer the duration of Medicaid coverage, the larger the predictive margin on the number of ED visits (see Table 4.14). With all other variables held at their observed values, the predictive margin on the number of ED visits among women with the longest Medicaid coverage (at least 280 days) was 1.117 visits, followed by 0.861, 0.607, and 0.361 for coverage at 279 to 188 days, 187 to 95 days and fewer than 95 days, respectively. These predictive margins on the number of ED visits also matched the factor and percent change findings. For example, the expected number of ED visits for women with at least 280 days of Medicaid coverage was 29.7% higher than for women in the reference group (coverage of 279 days to 188 days) The expected number of ED visits for women between 187 and 95 days of Medicaid coverage was 29.6% lower than for women in the reference group.

As shown in Table 4.15, comparing with the reference group (279-188 days coverage), and holding all other variables in the model at their observed value, the average marginal effects of women with the longest Medicaid coverage was estimated at 0.256 and was statistically significant ( $z = 14.08$ ,  $p < .05$ ). The average marginal effects of women with coverage of between 187 and 95 days was estimated

at -0.255 and was statistically significant ( $z = -11.30, p < .05$ ). The average marginal effects of women with coverage of between 94 days and 1 day were estimated at -0.501 and was statistically significant ( $z = -20.41, p < .05$ ).

These results showed that compared with the reference group (279-188 days), having the longest coverage increased the predicted number of ED visits by 0.256; having coverage of between 187 and 95 days decreased the predicted number of ED visits by -0.255; and having coverage of between 94 days and 1 day decreased the predicted number of ED visits by -0.501.

#### **4.4.6 Inpatient Admission 24 Hours After ED Visit**

As shown in Table 4.14, the predictive margin on the number of ED visits for inpatient admission was estimated at 1.50 visits, holding all other variables in the model at their observed values. The predictive margin on the number of ED visits by pregnant women who were not admitted and pregnant women who did not visit the ED (reference group) was estimated at less one visit (0.892). These results coincide with factor and percent change findings. The expected number of ED visits by women who were admitted to inpatient care was 68.1% higher than for women in the reference group. The difference on the number of ED visits between these two groups was 0.608, which is the same as the average marginal effects for this variable, holding all other variables at their observed value. As shown in Table 4.15, the average marginal effect was statistically significant ( $z = 19.19, p < .05$ ). This means that, compared with the reference group, one can expect the number of ED visits by women admitted to the inpatient service to increase by 0.608. In other words, the difference in the number of ED visits between women admitted to the inpatient

service and the reference group was 0.608 and statistically significant, as noted above.

#### **4.4.7 Maternal Related ED Visit**

The results from the model demonstrated that the variable for maternal related ED visits had the largest impact on ED visits. As shown in Table 4.14, the predictive margin on the number of ED visits for maternal related visits was estimated at 2.136 visits, holding all other variables in the model at their observed values. On the contrary, the predictive margin on the number of ED visits by pregnant women who did not visit the ED and pregnant women who visited the ED for other health-related conditions (reference group), was estimated at only 0.206 visits. These results coincide with the factor and percent change findings. The expected number of ED visits by women who visited the ED for maternal related conditions was 935.4% higher than for women in the reference group. The difference in the number of ED visits between these two groups was 1.930, which is the same as the average marginal effects for this variable, holding all other variables in the model at their observed value. As shown in Table 4.15, the average marginal effect was statistically significant ( $z = 95.54$ ,  $p < .05$ ). This means that, when compared with the reference group, one can expect the number of ED visits to increase by 1.930. In other words, the difference in the number of ED visits between women with maternal related conditions at the ED visit and the reference group was 1.930 and statistically significant, as noted above.

Table 4.14: Predictive Margins on the Number of ED Visits by Race/Ethnicity, Disability, Duration of Medicaid Coverage, Inpatient Admission, and Maternal Related ED Visit

	Predictive Margins on the Number of ED Visits	Delta-Method				
		Standard Error	z-value	P>z	95% Confidence Interval	
<b>Race/Ethnicity</b>						
Asian or Pacific Islanders	0.710	0.0551	12.89	0	0.602	0.818
Black	1.054	0.0121	86.77	0	1.030	1.078
Caucasian	0.969	0.0124	78.39	0	0.945	0.993
Hispanic or Latina	0.707	0.0171	41.35	0	0.673	0.740
Amer Indian or Alaskan	0.680	0.1654	4.11	0	0.356	1.004
<b>Disability</b>						
No	0.959	0.0080	119.37	0	0.943	0.975
Yes	1.179	0.0388	30.39	0	1.103	1.255
<b>Medicaid Coverage</b>						
>=280 days	1.117	0.0109	102.40	0	1.096	1.139
<=279-188 days	0.861	0.0145	59.34	0	0.833	0.890
<=187-95 days	0.607	0.0175	34.61	0	0.572	0.641
<=94-1 days	0.361	0.0199	18.08	0	0.321	0.400
<b>Inpatient Admission</b>						
No	0.892	0.0079	113.37	0	0.877	0.907
Yes	1.500	0.0305	49.19	0	1.440	1.559
<b>Maternal Related ED Visit</b>						
No	0.206	0.0039	53.08	0	0.199	0.214
Yes	2.136	0.0197	108.67	0	2.098	2.175

Table 4.15: Average Marginal Effects

	Average Marginal Effects (dy/dx)	Delta-method			P>z	95% Confidence Interval	
		Standard Error	z-value				
Age	-0.013	0.0015	-8.81	0	-0.0159	0.0101	
Charlson Comorbidity Index	0.125	0.0108	11.56	0	0.1035	0.1458	
Obstetric Comorbidity Index	0.053	0.0051	10.21	0	0.0425	0.0627	
Race							
Asian or Pacific Islander	-0.259	0.0564	-4.58	0	-0.3690	-0.1480	
Black	0.085	0.0173	4.91	0	0.0510	0.1189	
Caucasian	0	(base)					
Hispanic or Latina	-0.262	0.0209	-12.53	0	-0.3031	-0.2211	
Amer Indian or Ala	-0.289	0.1658	-1.74	0.081	-0.6139	0.0359	
Medicaid Coverage							
<=279-188 days	0	(base)					
>=280 days	0.256	0.0182	14.08	0	0.2203	0.2916	
<=187-95 days	-0.255	0.0226	-11.30	0	-0.2990	0.2106	
<=94-1 days	-0.501	0.0245	-20.41	0	-0.5490	-0.4528	
Disability							
No	0	(base)					
Yes	0.220	0.0397	5.53	0	0.1419	0.2976	
Inpatient Adm							
No	0	(base)					
Yes	0.608	0.0317	19.19	0	0.5457	0.6698	
Maternal Rel. ED V							
No	0	(base)					
Yes	1.930	0.0202	95.54	0	1.8901	1.9693	

## **Chapter 5**

### **SUMMARY OF FINDINGS**

The results of this study are based on investigating ED utilization among pregnant women using a methodology appropriate for count data. As noted in Chapter 2, ED utilization in previous studies among this population was operationalized as a dichotomous variable. This study uses the Negative Binomial regression model to predict the number of ED visits among pregnant women during the prenatal period and provides more information on ED utilization than when ED visits are operationalized as a dichotomous variable. The first section of this chapter summarizes the findings. Section 5.2 illustrates how the model can be applied.

#### **5.1 Summary of Findings**

The study found that ED utilization among pregnant women during the prenatal period was common. Based on Medicaid data collected in the state of Delaware over a 5-year period, the findings revealed that 40.5% (9,649 out of 23,824) of pregnant women enrolled during the study timeframe used the ED, and collectively, made a total of 22,883 ED visits. The total number of ED visits made by each pregnant woman who visited the ED ranged from one to as many as 25. Several sociodemographic variables associated with ED visits had a direct impact on the number of ED visits. Results from the model revealed that younger pregnant women utilized the ED more than other women in the study cohort. Black pregnant women visited the ED more than women of other race/ethnic groups, followed by Caucasian

women, and Asian/Pacific Islanders. Pregnant women with a disability were associated with more ED visits than pregnant women without a disability. Several clinical factors were also associated with ED visits. Pregnant women with higher health risks, measured by Charlson and Obstetric Comorbidity indices, visited the ED more than pregnant women with no or lower health risks. Pregnant women who were admitted to inpatient care within 24 hours of an ED visit utilized the ED more than those who were not admitted or those who never visited the ED. Pregnant women with maternal related conditions at the time of the ED visit utilized the ED more than those who visited for other health issues or never visited the ED. Last, pregnant women with longer duration of Medicaid coverage during the prenatal period utilized the ED more than women with shorter duration of Medicaid coverage.

Sections 5.1.1 to 5.1.8 provides a detailed discussion of the findings, organized by variables of interest.

### **5.1.1 ED Utilization**

This study found that 40.5% (9,649/23,824) of pregnant Medicaid beneficiaries utilized the ED at least once during their prenatal period. Of these women, the number of ED visits each ranged from one to 25. The total number of ED visits across the cohort was 22,883. The average number of ED visits across the full cohort, including those with and without an ED visit, was 0.96. Of those who visited the ED, the average number of visits during the prenatal period was 2.37. Of those who used the ED, 54.7% had two or more visits, 31.3% had three or more visits, and 19.0% had four or more visits.

In previous studies that included pregnant women who delivered live births across various settings in the United States, the percentages of pregnant women who

visited the ED during the prenatal period varied widely. For instance, in a national study using data from commercially insured women, Cunningham (2017) reported that 20% of pregnant women visited the ED at least once during the prenatal period. On the other hand, study authors from a single site reported 85% of pregnant women with public insurance or who were uninsured utilized the ED at least once during the prenatal period (Kilfoyle et al., 2017).

In studies of pregnant women enrolled in Medicaid, rates of ED visits ranged from 33% to 57.5%. Of those, only one study used Medicaid statewide data, similar to this study. The overall ED visit rate for pregnant women with at least one ED visit in that study was 57.5% which was higher than observed in our study as was the average rate across the total sample (1.6 ED visits). Of those who visited the ED, the average number of visits during the prenatal period was 2.79 (Vladutiu et al., 2019). While differences between the two studies were observed, comparing rates across these two studies, as well as across other studies, is problematic given the differences in study design, including their study settings, populations characteristics, variable definitions, and methodologies used. For example, Vladutiu et al. (2019) included not only visits made to the hospital ED, but also visits made to emergency obstetrical triage unit. On the other hand, Vladutiu et al. (2019) did not include ED visits that resulted in hospitalization in the analysis. This dissertation does not include emergency visits to emergency obstetric triage unit, but it does include all ED visits as well as visits that resulted in hospitalization. Last, visit rates may vary depending on health care policies, health care access, and care management at the time the study was completed (Daw et al., 2020; Metcalfe et al., 2018; Wherry & Miller, 2016).

### **5.1.2 Sociodemographic Factors**

In this dissertation, results from the model revealed that younger pregnant women utilized the ED more than other women in the study cohort. Black women visited the ED more than other races/ethnic groups, followed by Caucasian, and Asian/Pacific Islanders. Pregnant women with a disability were associated with more ED visits than non-disabled pregnant women. Findings relative to these three variables are discussed below.

#### **Age**

Age was found to be negatively associated with the number of ED visits; for one additional year increase in age, the expected number of ED visits decreases by 1.3%. Similarly, in terms of the marginal effects, the average marginal effect of age was also small (0.013). Of note, is that the percentage change and the average marginal effect of age appear small because the age variable was entered into the model as a continuous variable, meaning that the results reflected only a one-year change in age.

Additional results from the predictive margin on the number of ED visits for age, as shown in Table 4.11, also confirmed that younger pregnant women visited the ED more than older pregnant women. For example, the predictive margin on the number of ED visits when age was set at 20 years showed the estimated number of ED visits to be 1.033. However, the predictive margin on the number of ED visits declined to 0.739 when age was set at 45 years. In terms of predicted probabilities on the number of ED visits, the model also showed that the predicted probability of one visit among teenagers was almost 0.30, ranging from 0.277 among the youngest to 0.261 among the oldest teenagers, it gradually declined to only 0.211 among the oldest Medicaid recipients.

Our findings complemented studies that also found younger pregnant women were more likely to use the ED. However, not all studies reported similar findings and how age was categorized and reported across studies varied. In one study, adolescents were more likely to use the ED, albeit the variable was crudely defined as ages younger than 20 and older than 20 years old (Malik et al., 2017). In another study, women less than 25 years was associated with ED use (Varner et al., 2020). Last, results from Vladutiu et al. (2019) support increased ED use is associated with younger women ages 20 to 24 years (Vladutiu et al., 2019). The added value of this present study is age was used as a continuous variable to predict the number of ED visits. The model allowed estimates of the predictive margin on the number of ED visits for each unique age.

The findings of this dissertation also appear to complement other findings observed in studies of non-pregnant adults. In a review of nine articles focused on non-urgent visits, Uscher-Pines et al., (2009) found that six publications reported younger adults as being more likely to visit the ED compared to older adults (Uscher-Pines et al., 2013). An earlier review conducted by Carret et al., (2009) found that 14 of 16 studies reviewed by the authors also showed an inverse association between age and inappropriate use of ED (Carret et al., 2009).

As with other studies of pregnant women, this study cannot explain why younger pregnant women are more likely to use the ED. Further research on age would be useful given the limited data available on extreme maternal ages, both younger and older, when pregnancy risk factors are higher. In addition, research focusing on ED use among those who are primigravidae versus multigravidae may explain the effect of age on the number of ED visits.

### **Race/Ethnicity**

The model confirmed that pregnant Black women utilized the ED the most followed by Caucasian women; and then almost equal utilization by Hispanic or Latina and Asian/Pacific Islanders. Whether women were American Indian/Alaskan did not yield statistically significant results. Results from the model revealed that being Black increased the expected number of ED visits by 8.8% compared with the baseline reference group (Caucasian), while holding all other variables in the model at the observed values.

Results from the predictive margin on the number of ED visits for being Black was estimated at 1.05. The predictive margin on the number of ED visits for Caucasian, Asian/Pacific Islanders, Hispanic or Latina, and American Indian or Alaskan women were estimated at 0.968, 0.710, 0.707, and 0.680, respectively. Although the predictive margin on the number of ED visits between Asian/Pacific Islanders and Hispanic or Latina appear to be same and both estimates are significant at  $p < .05$ , it is important to note that the standard error for variable representing Asian/Pacific Islanders is about three times larger than standard error of variable representing Hispanic or Latina (0.055 versus 0.017). Therefore, at 95% confidence interval the predictive number of ED visits by Asian/Pacific Islanders ranges from 0.602 to 0.818 but the predictive number of ED visits by Hispanic or Latina only ranges from 0.673 to 0.740.

In their study, Kilfoyle (2017) concluded that after controlling for potential confounding factors in the model, the only two factors statistically significant for determining ED visits were lack of private insurance and a primary language other than English spoken at home. Age and race were not significant in the adjusted

model. The fact that insignificant results were obtained for race/ethnicity due to confounding factors in the model presented by Kilfoyle et al. (2017) may be explained by the small sample. Malik et al., (2017) in a study of more than 600 women in Kalamazoo County, Michigan, reported that non-white race was associated with ED visits (Malik et al., 2017). Our results are also similar to studies relating to ED use among non-pregnant adults. In a recent review that examined the relationship between race and utilization for non-pregnant populations, four of the nine articles found that those of Black race were more likely than Caucasians to use the ED for non-urgent visits (Uscher-Pines et al., 2013).

Race and ethnicity are important sociodemographic factors commonly used to examine health-care utilization and may serve as granular markers for health inequities in health-care access (Bingham et al., 2019). In a study of over 1,300 African American women recruited from a single site in a Detroit suburban hospital, 70% of all women had at least one ED visit (Ismailova et al., 2022). Although the present study shows that pregnant Black women used the ED more than pregnant women of other races/ethnicities, data are not available to explain why there are differences in ED utilization among different women. Further, while this dissertation shows that race/ethnicity was an important demographic factor, other demographic factors such as education, place of residence, and access to alternative health-care services may also be associated with predicting the number of ED visits.

#### **Presence of Disabilities.**

In this study, the total number of pregnant women with disabilities accounted for 3.5% of the study population. Of those, 58.1% visited the ED at least once. The model showed that being disabled increased the expected number of ED visits by

22.9% compared to women without disabilities, holding all other factors in the model constant. The predictive margin on the number of ED visits by women with disabilities was 1.179, whereas the predictive margin on the number of ED visits by women without disabilities was slightly less than one visit (0.959).

Similar to our study, Gavin et al. (2006) reported the proportion of women with disabilities who visited the ED at least once ranging from 49 to 57% in the four states included in the study (Gavin et al., 2006). This dissertation and the Gavin (2006) study confirmed that pregnant women with disabilities utilized the ED more than non-disabled pregnant women. Gavin et al., (2006), reported the adjusted odds ratio for ED visits among disabled pregnant women ranging from 1.22 (data from Texas) to 1.63 (data from Florida) (Gavin et al., 2006). In the present study, being disabled increased the expected number of ED visits by 22.9%. The results of this study also estimated the average marginal effects of pregnant women with disabilities visiting the ED was estimated at 0.220. It is important to note that it is difficult to compare the results of the two studies due to the differences in their methodological and analytical approaches of operationalizing ED visits.

There remain gaps in studying ED utilization during pregnancy for women with disabilities. Challenges remain in methodological approaches related to how women are classified as having a disability. Similar to Gavin et al., (2006) this dissertation identified women with disabilities using Medicaid eligibility pathway codes (also known as AID codes) at any time during pregnancy or delivery (Gavin et al., 2006). Women who had at least one pathway code were included, even if some codes during the prenatal period indicated a nondisabled category. As described in the literature review, Clements et al., (2018) classified women in her sample as having a

presumed physical, psychiatric, sensory, or intellectual disabling risk based on the Access Risk Classification (ARCS) algorithm (Clements et al., 2018). The intended goal of ARCS is to identify those who may need care coordination; in turn the tool tends to flag a substantial number of the population. Clements et al., (2018) acknowledged that although this tool has been used in the general adult population, this was the first time it has been used for this population and may need to be validated (Clements et al., 2018). Last, Mitra (2018) used a claims-based algorithm to identify her sample of women with IDD. In other studies of women with disabilities addressing research questions related to pregnancy outcomes (e.g., C-section rates; birth outcomes), similar algorithms were used, however, researchers tend to adjust them or build on published codes depending on their research intentions. Some researchers use a series of survey screening questions that self-identify disabilities such as “Do you think you have learning difficulties?” or “Are you limited in any way in any activities because of physical, mental, or emotional problems?” (Malouf et al., 2017). Aside from methodological approaches to identifying the study population as discussed above, investigators who have studied disabilities during pregnancy, note that disaggregating data by type of disability is important given that risks and needs may vary by physical, intellectual, developmental, and sensory disabilities (Darney et al., 2017).

Continued investigation of this subset is necessary to ensure that care is coordinated to enable pregnant women to juggle their prenatal visits alongside their other visits related to their disabilities, as well as dealing with obstetrical providers who may be unfamiliar with their special needs (Clements et al., 2018).

### **5.1.3 Comorbidity Indices**

Two comorbidity indices, the Charlson and the Obstetric Comorbidity Index, were entered into the model to measure different aspects of health risks for the study population. Results revealed that pregnant women with higher health risks visited the ED more than pregnant women with no or lower health risks. The findings revealed that an increase of one point in the Charlson Comorbidity Index and in the Obstetric Comorbidity Index, increased the expected number of ED visits by 13.7% and 5.6%, respectively, while holding all other factors in the model constant.

The predictive margin on the number of ED visits was 1.054 for women with a Charlson Comorbidity Index score equal to 1. As the score increased the expected number of ED visits increased. The predictive margin on the number of ED visits was 3.344 for women with a Charlson Comorbidity Index score equal to the maximum score of 10. The average marginal effect of the Charlson Comorbidity Index was 0.125. Moving onto the Obstetric Comorbidity Index, the predictive margin on the number of ED visits was 0.963 for women with a score equal to 1. As the score increased, the expected number of ED visits increased. The predictive margin on the number of ED visits was 1.843 for women with an Obstetric Comorbidity Index score equal to the maximum of 13. The average marginal effect of the Obstetric Comorbidity Index was 0.053.

While previous studies have confirmed that comorbidities are associated with increased ED utilization and are recognized as important explanatory variables for ED utilization, this study contributes to the discussion in several ways. First, comorbidities in previous studies of ED use among pregnant women were operationalized in a variety of ways. Unlike this dissertation, most authors reviewed source data (e.g., administrative datasets and/or medical records) for a specific set of

medical diagnoses and flagged women based on the presence or absence of the designated diagnosis. Selected comorbidities varied by study. For example, in a study on ED use among pregnant Medicaid recipients in North Carolina, the authors listed 11 medical comorbidities of interest (diabetes, chronic hypertension, preeclampsia, renal disease, etc.). The comorbidity variables were entered into the model as a nominal variable – that is, the presence of one medical comorbidities versus two or more comorbidities (Cunningham et al., 2017; Vladutiu et al., 2019) also used a list of “common” maternal comorbidities and measured the association between each comorbidity and ED use. Both studies operationalized comorbidities as binary variables. In this dissertation, women who may be at higher medical risk of using the ED were defined weighted indices (the Charlson Comorbidity Index and the Obstetric Comorbidity Index) rather than a list of diagnoses justified by the individual researchers.

Second, it appears that the Charlson Comorbidity Index has a higher impact on number of ED visits than the Obstetric Comorbidity Index. The difference in impact on the number of ED visits may be due to the distribution of scores for the two indices assigned to the population. Most pregnant women in the study had a 0 score (83.9%) or a score of 1(13.5%) on the Charlson Comorbidity Index, indicating a healthy population. The remaining women (2.6%) had score ranging from 2 to 9. None scored the maximum of 10. On the contrary, only 60.1% of women had a 0 score on the Obstetric Comorbidity Index; 18.1% had a score of 1; 12.2% had a score of 2; and 4.6% had a score of 3 in the index. The remaining 5% had a score ranging from 4 to 13. The skewed distribution of the Charlson Comorbidity Index and the relatively less skewed distribution of the Obstetric Comorbidity Index (see Figures

3.8 and 3.10) may have contributed to the significant difference in the factor or percent change between the Charlson Comorbidity Index and the Obstetric Comorbidity Index (13.7% versus 5.6%, respectively).

Use of indices allows comparison across study populations as well as changing patterns of comorbidity in the obstetrics population that could influence including ED use (Metcalf et al., 2018; Somerville et al., 2019). Further systematic exploration of applying these two indices to predicting ED utilization may be useful. Research may include, but should not be limited to, a closer look at patterns of ED use based on comorbidities, including research on types of comorbidities that have the most impact, use of preconception data, and stratification by social determinants.

#### **5.1.4 Duration of Medicaid Coverage**

The model used in this dissertation considered varying lengths of Medicaid eligibility during the course of the prenatal period. As described in the model, Medicaid coverage duration was defined as: (i) at least 280 days, (ii) 279 to 188 days, (iii) 187 to 95 days, and (iv) 94 days to 1 day before the delivery date. These categories were set based on administrative specification days from delivery established by the National Committee for Quality Assurance (NCQA) used to assess timeliness of prenatal care.

The model showed that overall duration of Medicaid coverage prior to delivery had an impact on the expected number of ED visits. Results from the model showed that pregnant women with longer duration of Medicaid coverage during the prenatal period utilized the ED more than women with shorter duration of Medicaid coverage. The expected number of ED visits for women with full duration of Medicaid coverage during the prenatal period was 29.7% higher than women in the

reference group (coverage 279 days to 188 days before delivery date), holding the other variables in the model constant. The expected number of ED visits by women with Medicaid coverage from 187 days to 95 days and from 94 days to 1 day prior to delivery was 29.6% and 58.1% lower, respectively, compared to women in the reference group. The predictive margins on the number of ED visits for women with at least 280 days of coverage was slightly more than 1 day, estimated at 1.117. Predictive margins for the remaining groups were 0.861, 0.607, and 0.361 for women with 279 days to 188 days, 187 to 95 days, and 94 to 1 days of coverage, respectively. In addition, average predicted probabilities on the number of ED visits showed that making one or more ED visits increased as the duration of Medicaid increased. For example, the average predicted probability of making one visit for women whose coverage was less than 95 days was 0.136 and gradually rose to 0.287 among women with full Medicaid coverage (at least 280 days).

Although the findings from the model regarding the duration of Medicaid coverage and the predicted number of ED visits were as expected (that is, the longer the coverage, the more visits), the patterns of ED visits among women with different durations of Medicaid coverage were more complicated than the model could capture. First, detailed data analysis of number of ED visits by trimester of pregnancy revealed that most ED visits occurred in the third trimester, regardless of duration of eligibility. In this dissertation, first, second, and third trimester accounted for 26.9%, 30.6%; and 42.6% of ED visits, respectively. When controlling for duration of Medicaid eligibility, the percent of ED visits continued to demonstrate that most ED visits occurred in the third trimester, ranging from 37.3% among women with Medicaid coverage (at least 280 days), to 46.3% and 72.5% among women with

Medicaid coverage for the period from 279 days to 188 days and 187 days to 95 days, respectively (see Table 5.1.) This finding was similar to a recent study of ED use among pregnant Medicaid recipients in North Carolina. In that study, about 28% of all ED visits occurred during the first trimester, 28% in the second, and 44% in the third trimester (Vladutiu et al., 2019). On the other hand, the findings from this dissertation and study conducted by Vladutiu et al., are opposite that of a study from Ontario, Canada, where residents have access to universal coverage. In that study, ED use among pregnant women who delivered a livebirth, was highest in the first trimester.

Table 5.1: Total Number of ED Visits by Trimester and by Duration of Medicaid Eligibility

Trimester*	Duration of Medicaid Eligibility				All Duration
	>=280 days	279-188 days	<=187-95 days	94-1 day	
First Trimester	5,141	1,005	--	--	6,146
<i>Percent</i>	32.0%	20.4%			26.9%
Second Trimester	4,944	1,637	413	--	6,994
<i>Percent</i>	30.7%	33.3%	27.5%		30.6%
Third Trimester	6,000	2,280	1,090	373	9,743
<i>Percent</i>	37.3%	46.3%	72.5%	100%	42.6%
All three Trimesters	16,085	4,922	1,503	373	22,883
<i>Total Percent</i>	100%	100%	100%	100%	100%

Second, as shown in Table 5.2, among pregnant women who made at least one ED visit, the average number of ED visits was highest during the third trimester among those with coverage less than 188 days indicating that women used the ED more (1.21 and 1.43 for those with coverage 187 days to 95 days and 94 days to 1 day, respectively). However, upon further review, while the average number of ED visits was higher among this group for third trimester use, only a relatively small

proportion appeared to be using the ED over and over (11.5% and 23.0%, respectively) (see Table 5.3).

Table 5.2: Average Number of ED Visits by Trimester and by Duration of Medicaid Eligibility

Trimester*	Duration of Medicaid Eligibility				All Duration
	>=280 days	279-188 days	<=187-95 days	94-1 day	
First Trimester	0.83	0.43	0.00	0.00	0.64
Second Trimester	0.80	0.71	0.46	0.00	0.72
Third Trimester	0.97	0.98	1.21	1.43	1.01
All three Trimesters	2.61	2.12	1.67	1.43	2.37
Total Number of Cases with One or More ED Visits	6,171	2,318	900	260	9,649

Table 5.3: Total Number of ED Visits by Study Population

*	Duration of Medicaid Eligibility				All Duration
	>=280 days	279-188 days	<=187-95 days	94-1 day	
Total Number of Cases with One or More ED Visits by Total Population	6,171/11,733	2,318/5923	900/3,908	260/2,260	9,649
<i>Percent</i>	52.6%	29.1%	23.0%	11.5%	

These findings raise several questions. First, it is not clear why a much smaller proportion of pregnant women (18.9%; 1,160/6,168) with shorter duration of Medicaid coverage visited the ED at least once compared to the 48.0% (8,489/17,656) of women with longer duration who visited the ED at least once. It has been hypothesized that those with shorter duration of prenatal coverage may, in fact, be less likely to seek care overall and hence use the ED less (Vladutiu et al., 2019).

Second, it is not clear why the average number of ED visits among pregnant women with shorter duration of Medicaid coverage was higher in the third trimester compared to those with longer coverage (that is, when controlled for duration of Medicaid coverage).

Third, it is not clear whether pregnant women with shorter duration of Medicaid coverage consist of women who entered prenatal care late. A study conducted at two hospitals in Kalamazoo County, Michigan, concluded that increased ED use was associated with late entry to prenatal care (Malik et al., 2017). It is also possible that women with shorter duration of Medicaid coverage represent women who moved in and out of Medicaid due to changes in eligibility status. It is common for low-income individuals to churn in and out of the Medicaid program for a variety of reasons. Given that Medicaid is determined based on income, beneficiaries may lose coverage when their income fluctuates, for example, individuals may work without benefits during seasonal work, only to reenroll in the program when their pay drops (Daw et al., 2020).

A closer look at the patterns of ED utilization among pregnant women with varied duration of Medicaid coverage during the prenatal period would provide further insights into the relationship between coverage and ED use, thus enabling appropriate policy measures to be developed.

### **5.1.5 Inpatient Admission 24 Hours after ED Visit**

This dissertation included ED visits that resulted in hospitalization as a proxy to measure the urgency of the ED visit and used this variable to predict the number of ED visits in the model. The results of this study revealed that the expected number of ED visits for pregnant women who were ever admitted to inpatient care 24 hours after

an ED visit was 68.1% greater than that for the pregnant women in the reference group who did not visit the ED or who visited ED but were not admitted to inpatient care, while holding other variables in the model constant. The predictive margins on the number of ED visits by women who were admitted to inpatient care was 1.500, whereas the predictive margins on the number of ED visits by women in the reference group was 0.892. The predicted probability of making one ED visit by women who were admitted to inpatient care 24 hours afterward was relatively high (0.312) however, predicted probability for a second, third, and fourth visit declined to 0.105, 0.027, and 0.006, respectively.

In the literature, ED utilization studies use urgent and non-urgent ED visits as the dependent variable with the intention of identifying determinants contributing to urgent and non-urgent use. In our study, urgent and non-urgent use was used as one of the independent variables to predict the number of ED visits. In addition to the results from the model, the data showed that among the women who were admitted to the inpatient service 24 hours after the ED visit, the average number of ED visits during the prenatal period was three; the average number of ED visits for those who were admitted to the inpatient unit more than twice was eight.

The results from the model suggest that close monitoring of pregnant women after discharge may prevent additional future ED visits for those women who had an urgent ED visit. In addition, coordinating the care by primary providers and the ED to identify these pregnant women may be useful given that some pregnant women do not follow up with their primary care provider after an ED visit.

### **5.1.6 Maternal Related ED Visits**

The results from this dissertation showed that pregnant women with a maternal related condition at the time of the ED visit utilized the ED more frequently than those who visited for other health issues, or never visited the ED. This variable had the greatest impact on the expected number of ED visits when compared with all other independent variables in the model. The expected number of ED visits for pregnant women who visited the ED for maternal related conditions was 935.4% more than for women who visited the ED for other health conditions and women who did not visit the ED. The magnitude of the difference in the predictive margins between visiting the ED for maternal related conditions (2.136 visits) and the baseline (0.206 visits) was estimated at 1.930 visits. Although the variable representing maternal related ED visits showed a large impact on number of ED visits when compared with the reference group, the predicted probability of making one ED visit by women who visited the ED for maternal related conditions was on par with the prediction of most other independent variable, estimated at 0.274. However, the predicted probability for the second, third and fourth visits were higher than for the other independent variables. This is because 61.5% (4,672/7,795) of all women who visited the ED for maternal related ED visits, visited the ED more than once.

A closer look at pregnant women who only used the ED, revealed that 7,595 women (78.7%) visited the ED for a maternal related condition; the remaining women visited for other health conditions. It is not clear why the proportion of women who visited the ED for maternal related conditions was high, although other studies have reported a high percentage of visits are classified as obstetric complications (Magriples et al., 2008).

When comparing general and obstetrics health risks, as measured by the Charlson and Obstetric Comorbidity Indices, there was no difference among pregnant women who visited the ED for maternal related conditions and those who visited for other health reasons. As shown in Table 5.4, the average Obstetric Comorbidity Index score of women who visited the ED for maternal related conditions was 1.08 and the average Obstetric Comorbidity Index score of women who visited the ED for other health conditions was 1.02. The scores were not statistically different from each other ( $t(3,346.2) = -1.14, p = .072$ ). The average Charlson Comorbidity Index score for women who visited the ED for maternal related conditions was 0.31 which was the same as the score for women who visited the ED for other health conditions ( $t(3,046.2) = 0.28, p = .611$ ).

Table 5.4: Average Scores of Charlson Comorbidity and Obstetric Comorbidity Indices for Pregnancy and Non-Pregnancy-Related ED Visit Among Women Who Visited the ED

Type of Index	Average comorbidity index score			Two-Sample t-test with Unequal Variances
	Cases with Non-Pregnancy Related ED visits	Cases with Pregnancy-Related ED visit	All Cases	
Obstetric	1.02	1.08	1.07	$t = -1.45^*$
Charlson	0.31	0.31	0.31	$t = 0.28^{**}$
Number of cases	2,054	7,595	9,649	

$p^* = .072; p^{**} = .611$

The fact that the general and obstetric health risks were the same for these two groups suggests that a number of pregnant Medicaid recipients may have used the ED for reasons that could have been addressed in a primary prenatal care setting rather

than the ED. These results raise two important policy and research questions related to access to prenatal care and behavioral decisions related to ED use by pregnant women. First, the high proportion of pregnant women visiting the ED for maternal related conditions may be related to adequacy of prenatal care. In a study conducted by (Magriples et al., 2008) that examined the association between prenatal care and ED utilization, the authors reported that pregnant women with inadequate prenatal care used the ED more than those with adequate prenatal care. Although this present study does not address issues of adequate versus inadequate prenatal care with respect to ED utilization, one could postulate that a proportion of the pregnant women who visited the ED for maternal related conditions may have had inadequate prenatal care. Alternatively, they may have had issues associated with access to prenatal care or simply have preferred to use the ED.

A third policy and research topic the high proportion of pregnant women who use the ED for maternal related conditions, is the associated unnecessary cost. From a cost management point of view, reducing and/or diverting ED visits that are being used as a substitute for prenatal care will decrease the financial burden on the state. In recent studies of ED costs, the average cost of an ED visit for those enrolled in public insurance was \$520, whereas the average standardized cost paid by Medicaid for a visit to a specialist, including obstetricians, was \$114 (Biener & Selden, 2017; Moore & Liang, 2020). Based on this rough cost comparison, \$400 could be saved each time by diverting inappropriate ED visits to a prenatal primary care provider. While this saving may not seem significant, there are several direct and indirect benefits that make incremental costs savings important. First, it would enable the state to properly allocate and manage resources directed to primary care. Second, it would alleviate ED

overcrowding. Last, it would reduce the fragmentation of care that ED use can lead to (Chen & Ayanian, 2014; Cheung et al., 2012; Kellermann et al., 2013; Morganti et al., 2013; Pitts et al., 2010; Shaw et al., 2013; Uscher-Pines et al., 2013). Pregnant women who can access routine prenatal care, rather than the ED, may benefit from continuity of care and related positive maternal and infant health outcomes. Further exploration, especially for inappropriate use, and cost analyses are needed.

## **5.2 Application of the Model**

This section demonstrates how the Negative Binomial model can be used to predict ED counts on the eight independent variables. The illustrations presented in this section serve as examples of how the explanatory model can be used for predicting the number of ED visits. Of note, this is not meant to be used as an a priori predictive model given that some of the independent variables in the equation are only available after the woman is enrolled in Medicaid and is receiving prenatal care including: Obstetric Comorbidity Index, whether the ED visit resulted in hospitalization, that is whether it was urgent or not, and whether the ED visit was a maternal related visit. An a priori predictive model for a woman at the time of entry into the Medicaid prenatal care system would require creating a model with a set of assumptions about these variables collected during prenatal care. Using assumptions would result in a model with a range of predictions on number of ED visits.

After reviewing the full explanatory model expression in Section 5.2.1, examples of how the model can be applied are illustrated using age (Section 5.2.2), disabilities (Section 5.2.3) and race/ethnicity (Section 5.2.4). Similar interpretations can be made among all independent variables represented in this explanatory model to predict the number of ED visits.



Using the above equation allows estimation of how the number of ED visits changes when a specific independent variable in the model changes. The following examples show how the equation is applied and how the approaches used to interpret the count model are interrelated.

### 5.2.2 Example 1: Age

The factor change for age was estimated at .987, as noted in the equation above, (see Equation 5.1). For every year increase in age, the predicted number of ED visits decreases by a factor of .987. The equation can also be used to estimate the predicted number of ED visits at a particular age. For example, when age is set at 20 years, the predicted number of ED visits is estimated at 1.033; when age is set at 21 years, the predicted number of ED visits is estimated at 1.019.

Since there is an exponential relationship between the predicted number of ED visits ( $y$ ) and the independent variables ( $x_i$ ) in the equation, a 1 unit increase in  $x_i$  has a multiplicative impact of  $\text{Exp}(\beta_i)$  on  $y$ . Thus, simply knowing the predicted number of ED visits for one age, can be enough to predict the number of ED visits for a 1-year increase in age. For example, the predicted number of ED visits at age 21 can be estimated by multiplying the factor change (.987) by the estimate for the predicted number of ED visits at age 20 (1.033) which equals 1.019. The predicted number of ED visits at age 22 can be estimated using  $.987 \times 1.019$  and so forth for each 1 unit increase in age.

As the factor change and predicted number of ED visits are related to the percent change, the percent change in the expected count for a unit change in  $x_k$ , can be computed as the following:

$$100 [\exp(\beta_k \times 1) - 1]$$

For age, the model demonstrated that for every additional year increase in age, the predicted number of ED visits was expected to decrease by 1.3% ( $[100(0.987 - 1)]$ ), holding all other variables in the model constant at their observed values. Percent change can also be calculated using estimates of the predicted number of ED visits. Using the examples in this section for ages 20 and 21 years, we would expect the predicted number of ED visits to be 0.014 lower (1.033-1.019). This is equal to a 1.3% ( $0.014/1.033$ ) decrease in the predicted number of ED visits.

### **5.2.3 Example 2: Disabilities**

The factor change for the disability variable was estimated at 1.229, (see Equation 5.1). The predicted number of ED visits is expected to increase by a factor of 1.229 for those with disabilities, compared to women without disabilities. The equation can be used to estimate the predicted number of ED visits for pregnant women with a disability, by assigning for the dummy variable either 1 to represent disability or 0 to represent no disability, while holding all other variables constant at their observed values. When set at 1, the predicted number of ED visits for pregnant women with a disability is estimated at 1.179; on the other hand, when the variable is set to 0, the predicted number of ED visits by pregnant women without a disability is estimated at .959. Given that this is a dummy variable, the difference in the predicted number of ED visits is the same as the average marginal effect for disability.

Like age, there is an exponential relationship between the predicted number of ED visits ( $y$ ) and the independent variables ( $x_i$ ) in the equation, meaning that a 1 unit increase in  $x_i$  has a multiplicative impact of  $\exp(\beta_i)$  on  $y$ . Therefore, the predicted number of ED visits for pregnant women with a disability can be estimated by

multiplying factor change (1.229) by the estimate for the predicted number of ED visits for pregnant women with no disabilities (.959) which equals 1.179.

As the factor change and predicted number of ED visits are related to percent change, the percent change in the expected count for a unit change in  $x_k$ , can be computed as follows:

$$100 [\exp (\beta_k \times 1) - 1]$$

For disabilities, the model demonstrated that being disabled increased the expected number of ED visits by 22.9% ( $[100(1.229 \times 1)-1]$ ), compared to the reference group. For dummy variables, the percent change can also be calculated using the estimates of the predicted number of ED visits. Using the example of being disabled or not, we would expect the predicted number of ED visits by disabled pregnant women to be 0.220 higher (1.179-0.959) than the predicted number of ED visits by pregnant women who are not disabled. This is equal to a 22.9% (0.220/0.959) increase in the predicted number of ED visits.

#### **5.2.4 Example 3: Race/Ethnicity**

The factor change for the race/ethnic variable for Black women was estimated at 1.08, (see Equation 5.1). The predicted number of ED visits is expected to increase for Black women by a factor of 1.08, compared to the reference group. As with disabilities, race/ethnicity also uses a dummy variable. The equation can be used to estimate the predicted number of ED visits for race/ethnicity by assigning 1 for the race/ethnicity dummy variable of interest and assigning 0 for all other dummy variables representing race/ethnicity. For example, when set at 1 for Black women, the predicted number of ED visits is estimated at 1.054, while holding all other independent variables in the model constant at their observed values. Using the same

methods to assign values, the predicted number of ED visits for Hispanic or Latina, Asian Pacific Islander and American Indian or Alaskan women are estimated at 0.707, 0.710, and 0.680, respectively. Since Caucasian was the reference group, all race/ethnic dummy variables were assigned 0 and predicted number of ED visits was estimated at 0.969. As with disabilities, given that this is a dummy variable, the difference in the predicted number of ED visits for the race/ethnicity group of interest was the same as the average marginal effect for Black women ( $1.054 - 0.969 = 0.085$ ).

Since there is an exponential relationship between the predicted number of ED visits ( $y$ ) and the independent variables ( $x_i$ ) in the equation, a 1 unit increase in  $x_i$  has a multiplicative impact of  $\exp(\beta_i)$  on  $y$ . Using Black race as an example, the predicted number of ED visits for Black pregnant women can be estimated by multiplying factor change (1.088) by the estimate for the predicted number of ED visits for the reference group (0.969) which equals 1.054.

As the factor change and predicted number of ED visits are related to percent change, the percent change in the expected count for a unit change in  $x_k$ , can be computed as follows:

$$100[\exp(\beta_k \times 1) - 1]$$

The model demonstrated that being Black, increased the expected number of ED visits by 8.8% ( $[100(1.088 \times 1) - 1]$ ), compared to the reference group. For dummy variables, the percent change can also be calculated using the estimates of the predicted number of ED visits of the variable of interest. Using the example of Black race compared to the reference group, we would expect the predicted number of ED visits by Black women to be 0.085 higher ( $1.054 - 0.969$ ) than the predicted number of ED visits by pregnant women in the reference group. This is equal to an 8.8%

$([1.054/0.969] - 1)$  increase in the predicted number of ED visits. Similar comparisons between variables representing race/ethnicities can be summarized using the same approach as discussed in this paragraph.

## **Chapter 6**

### **STUDY STRENGTHS, LIMITATIONS, FURTHER RESEARCH AND POLICY IMPLICATIONS**

This dissertation makes a significant contribution to the literature by describing the extent to which pregnant women enrolled in the Delaware Medicaid program use the ED, the characteristics of those women, and the sociodemographic and clinical variables that contribute to the number of ED visits (counts) among the study population. Identifying and understanding the factors associated with ED use that can be used to predict the number of ED visits among pregnant Medicaid recipients is an important step in informing, developing, and driving evidence-based practice and policy responses for pregnant women enrolled in Medicaid who use the ED. Without these data, the design and study quality of follow-up interventions are hampered by lack of information about the patient population.

The final chapter of this dissertation provides a summary discussion in four areas. Section 6.1 outlines the study strengths and is followed by a discussion of study limitations (Section 6.2), future research (Section 6.3) and policy implications (Section 6.4).

#### **6.1 Study Strengths**

The study strengths are outlined in this section. First, this study focuses on ED use among pregnant women, a population that has special needs and health care seeking behaviors (Foley et al., 2013; Tang et al., 2010). Also, the field of study for ED use is evolving for this population.

Second, this study provides more information on ED use by pregnant women during the prenatal period by operationalizing ED visits as a discrete number (i.e., 0, 1, 2, 3...) rather than as a binary variable as has been done in previous studies.

Third, although nationally representative samples may be a powerful option for studying ED use, using state-level data is important given that there are variations in how the ED is utilized among states that many national datasets cannot tease out. State-level data are essential for those in the Medicaid program responsible for health-care management decisions that impact overall access, as well as efficient and effective access for this population (Office of the Assistant Secretary for Planning and Evaluation, 2021). Using state-level data offers insights into how Medicaid beneficiaries in the state are accessing care and may inform how programs need to be developed, altered, or strengthened at the state-level.

Fourth, this dissertation offers the opportunity to understand baseline utilization patterns during the prenatal period and to test timely hypotheses about ED use in the context of ongoing health-reform measures, such as Medicaid expansion policies, predicted primary-care providers shortages, changing health status among pregnancy women, and, beginning in 2020, reported changes in ED use during a COVID-19 pandemic.

Fifth, research conducted for this dissertation demonstrated that the state administrative database is a useful source of data for studying ED use for this unique patient population. Data were analyzed to predict number of ED visits and identify factors contributing to ED utilization for pregnant Medicaid beneficiaries. In addition, given the advances in computing technology, it is conceivable that administrative

databases can be utilized to study, and develop real-time responses to address ED utilization for this population (Isasi, 2015).

Last, this dissertation moves beyond single site hospital settings, convenience samples, and observational designs. The study population was selected using data from more than 20,000 Medicaid beneficiaries who delivered over a 5-year period.

## **6.2 Study Limitations**

The results from this dissertation provides useful information and contributes to the emerging body of evidence and community of knowledge regarding ED utilization among pregnant Medicaid beneficiaries. However, there are several limitations. Section 6.2.1 discusses three limitations related to the selected study population for this dissertation. Section 6.2.2 delineates limitations related to the data and the model specification.

### **6.2.1 Criteria for Selecting Study Population**

First, study inclusion criteria were limited to pregnant women who delivered live births. This study does not include pregnant women who may have used the ED but ultimately did not deliver a live birth; for example, women who accessed the ED but for whom pregnancy ended in miscarriage, ectopic pregnancy, and/or incomplete, missed, or complete abortion, or stillbirth. This is an important distinction for policy makers who may be interested in understanding ED use patterns for all pregnant women, regardless of birth outcome.

Second, all pregnant women were enrolled in Medicaid in the state of Delaware. Results are specific to this population and cannot be generalized to ED use

by pregnant women who are enrolled in insurance plans other than Medicaid, or who are uninsured.

Third, the population in this study represents pregnant women who delivered a live birth during the 5-year period ending in 2012. Given health-care reform, changes in Medicaid policies, and documented temporal changes in the health status of pregnant women in the United States (Metcalf et al., 2018), the findings observed in this study may not resemble results of ED use for pregnant Medicaid recipients during other time periods. However, the results from this dissertation can serve as a baseline for comparing ED use before and after implementation of the Patient Protection and Affordable Care Act and Medicaid expansion.

## **6.2.2 Data and Model Specification**

First, while measures were taken to increase the accuracy and the quality of the data, due to the nature of state Medicaid datasets, the data used in this study may be subject to data entry errors, inconsistent and inaccurate coding, and misclassification that in turn may have impact on the study variables (Palmsten et al., 2013; Palmsten & Chambers, 2018).

Second, the model and analyses relied on anonymized, de-identified Medicaid data. As a result, the variables included in the model were limited to what was available in the dataset. Access to protected health information may yield details about ED use that were otherwise not available.

Third, ED visits were identified using the UDMRP code book for place of service. This ED service code does not distinguish between women who may have accessed the hospital's main emergency, a dedicated obstetric emergency department

that provides pregnant women immediate access to a trained obstetrics physician, or hospitals that use an obstetric triage model for pregnant women.

Last, measures of health care seeking behavior that may explain ED utilization were not available for this population, including measures of adequacy of prenatal care based on attending prenatal visit attendance, as well as utilization of service setting for unscheduled visits other than the ED, such as obstetric triage units, maternal-fetal specialty clinics, and primary care settings.

### **6.3 Future Research**

This study presents another approach for investigating ED utilization among pregnant women during the prenatal period by operationalizing ED visits as an actual count of the number of visits, as opposed to a dichotomous variable. The findings from this dissertation provide additional knowledge that can be used for practice and policy interventions. However, research gaps remain; if these are addressed, it could further enhance the findings from this study. In so doing, program theory, design, and logic can be defined that makes sense for the pregnant women population and their specific health problems.

First, while this dissertation showed, for example, that younger, Black, pregnant women with disabilities used the ED more, as well a large number of maternal related visits, results are not available to explain why. Addressing gaps in understanding the behavioral factors and health care seeking behaviors that influence why pregnant women use the ED may elucidate the findings in this model. This could be done in several ways. First, the model and the analysis could be enhanced by including data from birth records. Second, the model and analysis could be supplemented with more detailed survey data from a subset of the study population.

Data from a mixed methods (e.g., survey and interview) study may elucidate the findings in the model. Last, departing from the existing model, one could conduct a qualitative study to expand on the findings from this study.

Second, efforts to expand research focused on urgent and non-urgent ED visits should be undertaken. In this case, urgent and non-urgent visits could serve as the dependent variable rather than using the predicted number of ED visits as the dependent variable. This includes exploring alternative methods to define urgent and non-urgent visits.

Third, although interaction terms between independent variables were not included in the model, it is conceivable that there may be some interaction effects among two (or more) independent variables. In this case, the outcome of the dependent variable could be affected by a combination of the values of two (or more) independent variables. If statistically significant, the combined effects of the predictors on the dependent variable will differ from the sum of their individual effects. The effect of the interaction term could be greater than or less than what is expected on the outcome, as indicated by the positive or negative sign of the interaction effect (Berrington De Gonzalez & Cox, 2007; Cohen, J. et al., 2003). For example, in the present study, the predicted number of ED visits is reported for Black women, holding all other variables in the equation constant. We might theorize that the predicted number of ED visits for Black women could depend on age and introduce an interaction term in the equation of Black race and age.

However, due to the exponential function in non-linear models (such as the Poisson and Negative Binomial regression equations), interpreting and testing coefficients for interaction terms is not straightforward. Whereas the interpretation

and testing for interaction terms in linear models is well-established, statisticians and econometricians continue to discuss how to interpret and test coefficients of interaction terms in non-linear models (Ai & Norton, 2003; Leitgöb, 2014; Mize, 2019).

In a seminal article reviewing published papers that used interaction terms in nonlinear models, Ai and Norton (2003) reported that the coefficients of the interaction terms were interpreted incorrectly (Ai & Norton, 2003). Using statistical theory, the authors demonstrated four reasons why interaction terms in nonlinear models cannot be interpreted as they are in linear models. The authors outlined the reasons as follows: (1) in nonlinear models the interaction effect could be significant (non-zero) even if the coefficient of the interaction term is equal to zero (that is,  $\beta_{12} = 0$ ); (2) the statistical significance of the interaction effect in a nonlinear model cannot be tested with a single t-test on the coefficient of the interaction term; (3) because the interaction effect may have different signs for different values of covariates, the sign of the coefficient of the interaction term ( $\beta_{12}$ ) does not necessarily indicate the sign of the interaction effect; and (4) the interaction effect in a nonlinear model is conditional on the other independent variables in the model, unlike the interaction effect in linear models. Leitgöb (2014) expanded and confirmed the work of (Ai & Norton, 2003) to illustrate the complexity of interpreting and testing interaction terms in the Poisson and Negative Binomial count models. (Leitgöb, 2014).

In order to fully interpret interaction effects, Leitgöb (2014) demonstrated that there are three interaction effects in the count model: the total interaction effect, the model inherent interaction effect, and the product term induced interaction effect (Leitgöb, 2014). Moving forward, in a more recent study Mize (2019) concluded that

despite recent guidance from the editors of the *American Sociological Review* not to use the product of the coefficient to interpret interaction terms, researchers continue to interpret coefficients incorrectly in nonlinear models by simply using the product term to determine the significance of the interaction effect (Mize, 2019). The correct way to interpret and test an interaction term has not been thoroughly reviewed (Mize, 2019; Mustillo et al., 2018). In order to move the field forward, Mize (2019) offers some suggestions as to how to approach interpreting and testing interaction effects (Mize, 2019). In this model, future studies opting to include interaction terms will first require a thorough review of the evolving literature on statistical theory and practices for interpreting and testing interaction effects in nonlinear models.

Fourth, costs associated with ED use are one of the highest-profile concerns among policy officials responsible for public insurance and assistance programs. Based on the results of this dissertation, future research on the cost and benefits of ED utilization should be explored for this patient population. If incremental savings are possible, those savings could be shifted to invest in preventive models, and/or address other issues that might be related to ED use as provided by evidence that emerges from the research.

Last, this study used Andersen's model to conceptualize ED use and focused on the characteristics of the pregnant women. Expanding research trajectories beyond the scope of this dissertation and model to include other aspects of Andersen's conceptual, multilevel framework would be important in furthering the understanding of ED use for this population. Examples of determinants such as social determinants of health, access to and location of health care system facilities, number of care providers, and health policies are just some examples of contextual, individual, and

behavioral determinants that would provide further insights into ED use. Researchers acknowledge that questions remain as to whether ED utilization is a necessary complement to prenatal care as opposed to a substitute for prenatal care (Cunningham et al., 2017; Graves et al., 2019; Matteson et al., 2008).

#### **6.4 Policy Implications**

This dissertation lends itself to policy recommendations and implications, as discussed in this section. First, directly related to this dissertation is the recommendation to continue to strengthen availability of and access to statewide datasets. In addition, some states have successfully linked claims, discharge records, vital statistics, and program data. Linking and harmonizing datasets will allow for further research and evaluation of ED use for this population before, during, and after pregnancy.

Second, studies of ED use, particularly those presenting national, regional, or state data, accessed data from 6-10 years prior to the publication date. It is possible that this reflects a difficulty in accessing data and/or resources needed to use and analyze the data. Given the advances in computing technology, it is conceivable that with proper access and resources, Medicaid administrative databases can be utilized to study, assess, and develop proactive, real-time responses to ED use, by, for instance, using count methods as demonstrated in this study.

A third recommendation is to use evidence from this study to test and evaluate various care-innovation models and programs that have been advocated to reduce ED visits. These include but are not limited to using health information technology to improve the coordination of care; initiating case management at the ED during the prenatal period; setting up education and outreach programs to encourage

beneficiaries to use the most appropriate setting for care; offering primary prenatal care in the evening, on weekends and/or with walk-in hours or same day appointments; and using the maternity medical home model (Goyal et al., 2015; Hsia & Niedzwiecki, 2017; Rakover, 2016; Stergiopoulos et al., 2016; Suhag et al., 2017; Uscher-Pines et al., 2013). Research has revealed that increased ED use in the postpartum period is associated with ED utilization during the prenatal period, as well as late entry into prenatal care (Ehrenthal et al., 2017). Considering prenatal innovations and programs design to reduce ED use may also impact ED use during the postpartum period for this population.

Last, juxtaposed against the need for ongoing research for this population, is the importance of viewing ED utilization in relation to the role the environment (e.g., poverty, education, stress), differences in care received, and how structural inequities may impact ED utilization. Capitalizing on opportunities to understand the impact of health inequalities on ED use can begin with policy and programs and may be an important step in explaining why women use the ED during the prenatal period (Almeida et al., 2021; Goyal et al., 2015; Howell, 2017).

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## **Appendix A**

### **LITERATURE REVIEW METHODS AND SUMMARY TABLES**

The major formative publications for the literature review for this dissertation were identified in several ways. First, a search strategy using Medical Subject Headings (MESH) terms related to pregnancy, hospital, utilization, health care utilization, emergency services (hospital), health services accessibility, poverty, insurance, and Medicaid was conducted in PubMed followed by searches in other health databases. Second, relevant articles were used to establish citation chains. Last, in order to provide context for the dissertation discussion, the review also included determinants of ED use for by non-pregnant, adult populations. The search was limited to years 2008-2021. Articles were reviewed and eliminated if they did not focus on pregnant women and use of ED services as the dependent variable. References from several pertinent papers published prior to 2008 were included. Studies of ED use that used study data from outside the United States were reviewed for methods, themes, and other pertinent information to the study questions and design. Although there are differences in health care delivery systems, those studies were included in the synthesis of the literature given the sparse number of studies available and informative data (Ferriols Pérez et al., 2018; Thangarajah et al., 2018; Varner et al., 2020; Xu et al., 2017).

Key studies are listed in Tables 1-4. In addition to the study citation, Table 1 lists the data collection dates, data source and country, and sample size. Table 2 lists several important population characteristics. Table 3 provides a list of the study

variables (dependent and independent) and the methods. Table 4 provides a brief synopsis of the findings.

Table A.1: Literature Review: Data Source and Sample Size

Study Citation	Data Collection Dates	Data Source (and state/country)	Sample size
Gavin/ USA/ 2006	1995-1997 12 months of data from each state	Medicaid claims; vital statistics FL; GA; NJ; TX	32,455-79,198 Sample size differs across each state
Matteson/ USA/ 2008	2005	Medical records; patient survey RI	173
Magriples/ USA/ 2008	Not specified	CT and GA	420
Lee/ USA/ 2009	2005- 2006	Claims; medical records; vital statistics CT	3,296
Cunningham/ USA/ 2017	2010-2011	US national claims data	157,786
Malik/ USA/ 2017	2002-2003; 2009	Medical records; postpartum interviews	658
Kilfoyle/ USA/ 2017	2012	Medical records; postpartum interviews/survey RI	233
Mehta/ USA /2017	2014	Medical records; interviews; validated scales PA	40
Xu/ Australia/ 2017	2006-2010	Provincial health administrative data NSW, Australia	154,328
Ferriols Perez/ Spain/ 2018	2010-2011	Medical records Spain	668
Clements/ USA/ 2018	2007-2009	Pregnancy to Early Life Longitudinal data (PELL)	221,867

Study Citation	Data Collection Dates	Data Source (and state/country)	Sample size
		MA	
Thangarajah/ Germany/ 2018	2015-2016	Medical records; patient survey Germany	331
Vladutiu/ USA/ 2019	2008-2009	Claims data; vital statistics NC	107,207
Varner/ Canada/ 2020	2002-2017	Provincial health administrative data Ontario, Canada	2,700,000
Ismailova/ USA/ 2022	2009-2022	Medical records; interviews MI	1,410

Table A.2: Literature Review: Population Inclusion Criteria

Study Citation	Insurance	Age Range (years)
Gavin/ USA/ 2006	Public	Not specified. Less than or equal to 18 years; greater than 35 years
Matteson/ USA/ 2008	Public; Private; Uninsured	Not specified
Magriples/ USA/ 2008	Medicaid	14-24
Lee/ USA/ 2009	Public	20-44
Cunningham/ USA/ 2017	Private	18-44
Malik/ USA/ 2017	Public; Private	Not specified
Kilfoyle/ USA/ 2017	Public; Private; Uninsured	>18
Mehta/ USA /2017	Public	Not specified
Xu/ Australia/ 2017	Public; Private	<20-45+
Clements/ USA/ 2018	Public; Private	<19>=35
Thangarajah/ Germany/ 2018	National Health	Not specified
Ferriols Perez/	National Health	16-48

Study Citation	Insurance	Age Range (years)
Spain/ 2018		
Varner/ Canada/ 2020	National Health	10-55
Vladutiu/ USA/ 2019	Public	<19->=35
Ismailova/ USA/ 2022	Private;	18-45

Table A.3: Literature Review; Measures of ED Use

Study Citation	Outcome Measure (Dependent Variable)	Independent Variables	Analytic Methods
Gavin/ USA/ 2006	ED visits	Disabilities	Logistic regression
Matteson/ USA/ 2008	ED visits	Reasons for visiting the ED	Chi-square
Magriples/ USA/ 2008	ED visits	Demographics; medical history; psychosocial measure	Logistic regression
Lee/ USA/ 2009	ED visits	Sociodemographic; maternal history	Descriptive
Cunningham/ USA/ 2017	ED visits	Comorbidities; age, geographic location	Logistic regression
Malik / USA/ 2017	ED visits	Sociodemographic factors; psychosocial and health risk factors; maternal and fetal outcomes	Chi-square
Kilfoyle/ USA/ 2017	Urgent and Nonurgent ED use	Sociodemographic; maternal history; adequacy of prenatal care	Logistic regression
Mehta/ USA /2017	Low versus high ED use	Psychosocial; maternal history; adverse child experiences; visit	interview narratives; Chi-square

Study Citation	Outcome Measure (Dependent Variable)	Independent Variables	Analytic Methods
		acuity	
Xu/ Australia/ 2017	ED visits	Depression	Logistic regression
Clements/ USA/ 2018	ED use (and other health care utilization)	Disability risk factors	Cox regression; Chi-square
Thangarajah/ Germany/ 2018	ED utilization	Sociodemographic; maternal health	Fisher's exact
Ferriols Perez/ Spain/ 2018	ED visits by necessary, moderately necessary, and not necessary	Sociodemographic; maternal history	Chi-square; ANOVA
Vladutiu/ USA/ 2019	Low versus high ED use	Sociodemographic; maternal risk factors; maternal pregnancy history; comorbidities	Logistic regression
Varner/ Canada/ 2020	ED visits	Sociodemographic; maternal history; comorbidity	Logistic regression; modified Poisson Regression to generate adjusted RR
Ismailova/ USA/ 2022	ED visits	Counseling	Logistic regression

Table A.4: Literature Review: Findings

Study Citation	Findings
Gavin/ USA/ 2006	1-2% of all pregnant women were classified as disabled. The adjusted odds of women with disabilities having at least one ED visit were 1.2-1.6 times the odds of women without disabilities.
Matteson/ USA/ 2008	All women visited an OB/GYN ED; all were triaged as non-urgent; reasons for seeking care: women <20weeks more likely to report reason for visiting was a true emergency (44%); women greater than 20 weeks more likely to report a physician referred them to the ED; 86% were treated and released; 14% were admitted.

Study Citation	Findings
Magriples/ USA/ 2008	40% ED visit rate; 23% visit 2 or more times; ED visits associated with inadequate prenatal care and high symptom distress
Lee/ USA/ 2009	32% ED rate; descriptive data ED use associated with younger women under age 25; Hispanic women, smokers, inadequate prenatal care
Cunningham/ USA/ 2017	20% of all women made at least one ED visit; adjusted odds ratio revealed that women with any maternal comorbidities were more likely to use the ED; increased odds of seeking ED use were highest for those with asthma, followed by obesity, hypertension, diabetes, and gestational diabetes.
Malik / USA/ 2017	The following were associated with ED utilization: being an adolescent (younger than 20 years), non-white race, Medicaid beneficiaries, domestic abuse; prenatal smoking, use of recreational drugs, and inadequate antenatal care.
Kilfoyle/ USA/ 2017	84% of pregnant women had at least one visit to the ED; 35.6% of women had at least 1 visit to the ED that was nonurgent; increased odds of nonurgent ED use was associated with speaking a language other than English at home and public/no insurance. Women reported presentation to the ED for a true emergency (45%) or being referred by a health care provider (36%).
Mehta/ USA/ 2017	High utilizers were more likely to report they faced barriers to perinatal care; interview data also revealed the underlying reasons high utilizers sought ED care at the obstetrical triage unit were related to psychosocial vulnerabilities (such as, adverse childhood experiences, dysfunctional relationships and distrust, express limited coping strategies to address challenges of pregnancy, and continued anxiety about the current pregnancy) or preexisting illness and concern about symptoms.
Xu/ Australia/ 2017	ED visit rate 20.1%; highest rates for youngest age; non-immigrant; prenatal smoking; lowest income; inner regional
Clements/ USA/ 2018	Studied ED use among women using the Access Risk Classification System (ACRS). The ARCS includes a comprehensive list of diagnoses and conditions that classifies individuals based on presumed risk, rather than actual risk. Four percent of the sample were classified as medium to high risk. Findings revealed that women in the medium/high risk category for presumed disabling conditions were more likely to utilize the ED (37.1% medium/high risk versus 25.0% low/no risk).
Thangarajah/	No control group. Reason for ED visits: 45% referred; of those

Study Citation	Findings
Germany/ 2018	49.6% admitted; 52% no referral; of those 23% admitted. 56% triaged as nonurgent; no association between maternal characteristic and urgent / nonurgent; reported on number of tests and procedures completed in the ED.
Ferriols Perez/ Spain/ 2018	No control group. 668 women made 1,743 ED visits; of who made ED visits, 38.9% were defined as necessary; 46.7% as moderately necessary; and 14.4% as not necessary; as pregnancy advanced, ED visits were more likely to be classified “necessary.” Pregnancy risk level, parity, preterm births, miscarriage, stillbirth were not significant. Age was not associated with increased ED use.
Vladutiu/ USA/ 2019	ED rate 57.5%. Total number of ED visits 171,909; 202 per 1000 member months for the full sample; detailed analysis of high versus low only included women enrolled in Medicaid for most of the pregnancy. Of those, 18.1% of women were defined as high utilizers defined as 4 ED visits or more. High utilization was associated with younger age, Black race, lower education, tobacco use, late preterm delivery, multifetal gestation, more than one comorbidity.
Varner/ Canada/ 2020	Twenty percent of the total sample used the ED at least once; mean number of ED visits was 1.52. ED visits were more likely among women who were less than 25 years, nulliparous, and reside in the lowest income quintile geographic area, or rural areas, Canadian born, not seen by an obstetrician for prenatal care, more than one morbidity.
Ismailova/ USA/ 2022	70% had at least one ED visit; counseling topics covered during prenatal counseling/education were not associated with ED use except for slowed fetal movements and smoking.

## Appendix B

### MATERNAL RELATED ICD-9 DIAGNOSIS CODES

Medicaid recipients were coded based on whether the ED visit included a maternal related ICD-9 code. The following codes were used:

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Code	Diagnosis
640.00 to 649.82	Complications mainly related to pregnancy
650.00 to 659.93	Normal delivery, and other indications for care in pregnancy, labor, and delivery
660.00 to 669.94	Complications occurring mainly in the course of labor and delivery
671.03, 671.13, 671.23, and 671.83	Venous complications in pregnancy and the puerperium – only antepartum condition was included
V22.0 to V22.2	Normal pregnancy
V23.0 to V23.89	Supervision of high-risk pregnancy
V25.0 to V25.9	Contraceptive management
V28.0 to 28.9	Encounter for antenatal screening of mother
V72.4 to V72.42	Pregnancy examination or test, pregnancy unconfirmed
V89.09	Other suspected maternal and fetal condition not found
V9103	Twin gestation, dichorionic/diamniotic (2 placenta, 2 amnio sacs)

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